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Report Number 1

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PUBLIC HEALTH SERVICE

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SUMMARY

Public Health Service Water Pollution Surveillance System data from the main stem of the Missouri River for water years 1958 through 1962 were examined. Weekly determinations of chemical and biological characteristics of the Missouri River at seven stations from Williston, N. D., to St. Louis, Missouri show, in varying degrees, the pollutional effects of tributaries, impoundments, and waste discharges.

Concentrations of conservative (mineral) constituents were inversely proportional to flow, although this relationship was obscured in the upper reach because of regulation by reservoirs. Since flows were an estimated 94% of normal, average concentrations were slightly higher than would be expected over long periods. Both major and minor constituents were, except as noted below, well within limiting values for all beneficial uses. Municipal plants treating Missouri River water typically provide softening to correct for the usual 150 to 300 mg/l hardness. There were single occurrences of iron at Omaha, manganese at Bismarck, and sulfate at Omaha and St. Joseph at concentrations in excess of the Public Health Service Drinking Water Standards. There were increasing trends for hardness and alkalinity at most river stations. Turbidity and color were generally low in the upper reach because of sedimentation in reservoirs and high in the lower reach.

Dissolved oxygen levels were generally above 8 mg/l at and above Yankton. Minimum values of 4.0, 5.0, 3.2, and 4.0 mg/l at Omaha, St. Joseph, Kansas City, and St. Louis, respectively reflected municipal and

industrial waste discharges. Decreasing trends were observed at Omaha and St. Joseph. Similarly, BOD, COD, and chlorine demand concentrations showed effects of waste discharges in the lower reach.

Bacteriological examinations indicated local pollution at Williston, N. D. (probably from the sewage treatment plant effluent discharged seven miles downstream into Garrison Reservoir), values common to land drainage at Bismarck, lower levels below Gavin's Point Reservoir at Yankton, and gross pollution from municipal and industrial wastes at Omaha, St. Joseph, Kansas City, and St. Louis.

Radioactivity in the water varied with the season and with nuclear weapons testing. Alpha activity was from natural sources and accordingly varied with the suspended sediment in the water. Most of the beta activity and all of the Strontium-90 is man-made so that concentrations reflected weapons testing and seasonal runoff patterns. Levels of radioactivity were low and within acceptable limits, although values were increasing at the end of the study period.

Analyses of organic material collected by the carbon-filter method during late summer and fall showed the presence of dieldrin. These identifications are possible using extracts stored for more than five years, so that as new analytical techniques are developed the stored samples provide for determining historical patterns.

The plankton data indicate a diversified population which increased in total numbers, particularly pollution-tolerant species and genera. Oahe Reservoir was being filled during the study period, and it is possible that this change was being reflected.

It is concluded that present waters of the Missouri River are, with treatment, suitable for municipal and industrial uses. Recreational values are severely limited in the lower reach because of bacteriological pollution from municipal and industrial wastes. Those trends that were found were generally toward poorer water quality; scheduled construction of waste treatment facilities should provide for reversals of some of these trends.

CHAPTER I. INTRODUCTION

The Public Health Service program for providing fundamental information on the quality of the Nation's waters stems from Public Law 660, approved July 9, 1956, as amended by Public Law 87-88, July 20, 1961. Section 4(c) thereof states: ". . .the Secretary (of Health, Education, and Welfare) shall in cooperation with other Federal, State, and local agencies having related responsibilities, collect and disseminate basic data on chemical, physical, and biological water quality insofar as such data or other information relate to water pollution and the prevention and control thereof."

To fulfill this responsibility, the Public Health Service Water Pollution Surveillance System collects, interprets, and disseminates:

a. Information on changes in water quality at key points of use in river systems, as such quality may be affected by changes in water use and development.

b. Continuous surveillance of the nature and extent of pollutants affecting water quality.

c. Data which will be useful in the development of comprehensive water resources programs.

d. Data which will assist State, interstate, and other agencies in their water pollution control programs, and in the selection of sites for legitimate water uses.

This long-range program of sampling at a few points provides data on trends and support for water quality management activities during periods

between intensive investigations conducted by Public Health Service comprehensive water pollution control projects or special studies.

Information on a broad spectrum of water quality parameters has been provided by surveillance operations which began in 1957 with 50 stations throughout the country and which have subsequently been expanded to include 128 stations. The major portion of this effort is devoted to measuring and evaluating levels and changes in (1) 21 trace elements, including micronutrients and toxic metals which are normally found in concentrations ranging from a few tenths part per billion to perhaps one part per million; (2) selected classes of organic materials; (3) specific organic materials such as detergents and pesticides; (4) radioactivity from natural and man-made sources; (5) aquatic life, and (6) bacteriological quality. In addition, physical and chemical analyses of the common constituents of water are made to characterize the specific samples and to provide additional bases for evaluating the utility of the water. These common analyses provide for comparison with the often long-term records of physical and chemical quality at a large number of stations operated by State and local agencies, often in cooperation with the U.S. Geological Survey.

The present study is the first of a series which has the general objective of characterizing trends in quality of surface water supplies, including the Great Lakes and major river basins, insofar as they are affected by pollution. Only Public Health Service Water Pollution Surveillance System information is being evaluated in this series in order to assure homogeneous baseline data from which geographical or technical areas needing specific studies may be identified.

It is expected that each report in the series will identify particulars wherein the water pollution surveillance program should be changed and improved. Such changes will include the frequency of sampling, by designation of primary and secondary stations, and the addition or deletion of specific tests.

Method

Methods and frequency of sampling and analysis, which generally follow Standard Methods,[1] are described in the annual data compilations.[2-6, incl.] Active local participation is important in the program, and assures maximum development of all information valuable both locally and nationally. Program costs are shared by the Federal Government and State and local agencies, those of the latter through contributions of laboratory and sampling manpower. Specifically, the State and local agencies perform certain of the conventional chemical analyses and collect samples for the newer, more complex examinations. The Public Health Service, in turn, performs the more complex determinations and makes the results available to the participants and to the public. Quality control of data from local participants is maintained by use of analytical reference samples, consultation by staff specialists, training facilities, and other resources of the Public Health Service.

Data beginning in water year 1958 (October 1, 1957 to September 30, 1958) from seven stations on the main stem of the Missouri River have been analyzed in the present study. These stations include Williston, N. D.; Bismarck, N. D.; Yankton, S. D.; Omaha, Nebr.; St. Joseph, Mo.; Kansas City, Kans.; and St. Louis, Mo. An eighth station at Missouri City,

Mo. was not considered because of its limited period of record. Discharge data and associated river mileages are taken from USGS discharge records.[7-15, incl.] Other hydrologic information is from the Water Atlas of the United States[16] and appropriate USGS discharge records.

The general approach to data analysis has been to prepare a time-series for each parameter at each station. Analogs were plotted from magnetic tape by the Minneapolis-Honeywell 400 system. Determinations of present levels, cyclic variations and trends are based upon subjective curve-fitting and analysis.

Some of the parameters are treated in more detail than others; this is a reflection of the present state of the art. Methods for objective curve-fitting and other statistical analyses utilizing electronic data processing are being examined and it is expected that these methods will be available for later studies of this series.

Sampling Stations

Water quality at stations in the upper reach is determined by runoff from the tributary watersheads as modified by major reservoirs described in Chapter II. In the lower reach, however, waste discharges with an aggregate population equivalent of over 4-1/4 million markedly affect the water, particularly its bacteriological quality. The major discharges come from the cities listed in Table 1. Additional salient environmental features of the PHS Water Pollution Surveillance System stations supplying data for this study are summarized below:

Williston, North Dakota (mile 1553). Samples are taken from the intake of the municipal water plant which is within, and near the upstream limit of, Garrison Reservoir

Table 1

WASTE DISCHARGES TO LOWER REACH OF MISSOURI RIVER

	1960 Loading		1963 Status
City	Discharge	BOD Population Equivalent	(Primary treatment plant unless otherwise noted.)
Yankton, South Dakota	Raw	16,000	Under construction
Vermillion, South Dakota	Raw	6,000	Funding completed
Ponca, Nebraska	Raw	1,000	Under construction
Sioux City, Iowa(a)	Raw	492,000	Under construction
Dakota City, Nebraska	Raw	1,000	Engineering studies made
Blair, Nebraska	Primary Effluent	5,000	Completed 4/59
TOTAL YANKTON TO OMAHA		521,000	
Omaha, Nebraska	Raw	1,281,000	Under construction
Council Bluffs, Iowa	Raw	60,000	Completed 4/63
Nebraska City, Nebraska	Raw	20,000	Under construction
TOTAL OMAHA TO ST. JOSEPH		1,361,000	
St. Joseph, Missouri	Raw	139,000	Under construction
South St. Joseph Industries	Raw	485,000	Completed 12/63
Atchison, Kansas	Raw	33,000	Completed 8/62
Weston, Missouri	Raw	600	Completed 9/62
Leavenworth, Kansas	Raw	34,000	Completed 5/62
Lansing Penitentiary, Kansas	Primary Effluent	400	No change
Parkville, Missouri	Raw	1,000	No change
TOTAL ST. JOSEPH TO KANSAS CITY		713,000	
Kansas City, Kansas	Raw	639,000	Funding completed
North Kansas City, Missouri	Raw	120,000	Under construction
Kansas City, Missouri	Raw	746,800	Under construction
Independence, Missouri - West	Raw	47,300	Completed 9/62
Independence, Missouri - East	Secondary	3,000	No change
Liberty, Missouri	Raw	4,700	Funding completed
Lexington, Missouri	Raw	6,000	Completed 8/63
Waverly, Missouri	Raw	340	Completed 11/63
Algoa, Missouri	Raw	340	Completed 5/62
Chamois, Missouri	Raw	470	Completed 1/63
Hermann, Missouri	Raw	2,340	Completed 9/63
Glasgow, Missouri	Raw	850	No change
Boonville, Missouri	Raw	8,600	Design completed
Jefferson City, Missouri	Raw	25,600	Funding completed
New Haven, Missouri	Raw	1,220	Engineering studies made
Washington, Missouri	Raw	6,940	Engineering studies completed
St. Charles, Missouri	Raw	13,000	Design completed
Coldwater Creek, Missouri	Partially Treated	32,000	Secondary treatment plant under construction
TOTAL KANSAS CITY TO ST. LOUIS AT HOWARD BEND		1,681,100	
TOTAL YANKTON TO ST. LOUIS		4,276,100	

Note: (a) Including South Sioux City

(N48°08'30", W103°38'15"). The sewage treatment plant outfall is located about seven miles downstream at the same elevation.

Bismarck, North Dakota (mile 1314). This sampling station is at the municipal water plant intake (N46°48'51", W100°49'12"). When Oahe Reservoir is full, the station will be near the upstream limit of the pool.

Yankton, South Dakota (mile 805). The municipal water plant intake from which samples are taken is located at Yankton about six miles below Gavin's Point Dam (N42°51', W97°22').

Omaha, Nebraska (mile 626). Samples are taken from the intake of the Metropolitan Utilities District Water Plant (N41°20'40", W95°57'28"). This is the uppermost station which is affected by municipal and industrial waste discharges, mostly from the Sioux City area, 130 miles upstream.

St. Joseph, Missouri (mile 451). This station is at the St. Joseph Water Company treatment plant (N39°44', W94°52'). Water quality reflects the upstream waste discharges and the inflows from the Platte River.

Kansas City, Kansas (mile 374). The municipal water plant from which the samples are taken (N39°09'08", W94°38'30") is upstream from waste discharges in the Kansas City metropolitan area. Minimum flows maintained by the Corps of Engineers by releases from upstream reservoirs are 35,000 cfs. during the navigation season, usually May through October. During the rest of the year, effort is made to

maintain 9,500 cfs although as little as 5,000 cfs have occurred during ice conditions.

St. Louis, Missouri (mile 37). Two water plants are co-operating in the sampling operation. Samples for organic analyses and bacteriological examination are obtained from the St. Louis County Water Company plant at river mile 36.6 (N38°41'22", W90°32'04"). All other analyses are made on water from the City of St. Louis' Howard Bend Plant at mile 37.2 (N38°40'54", W90°32'42").

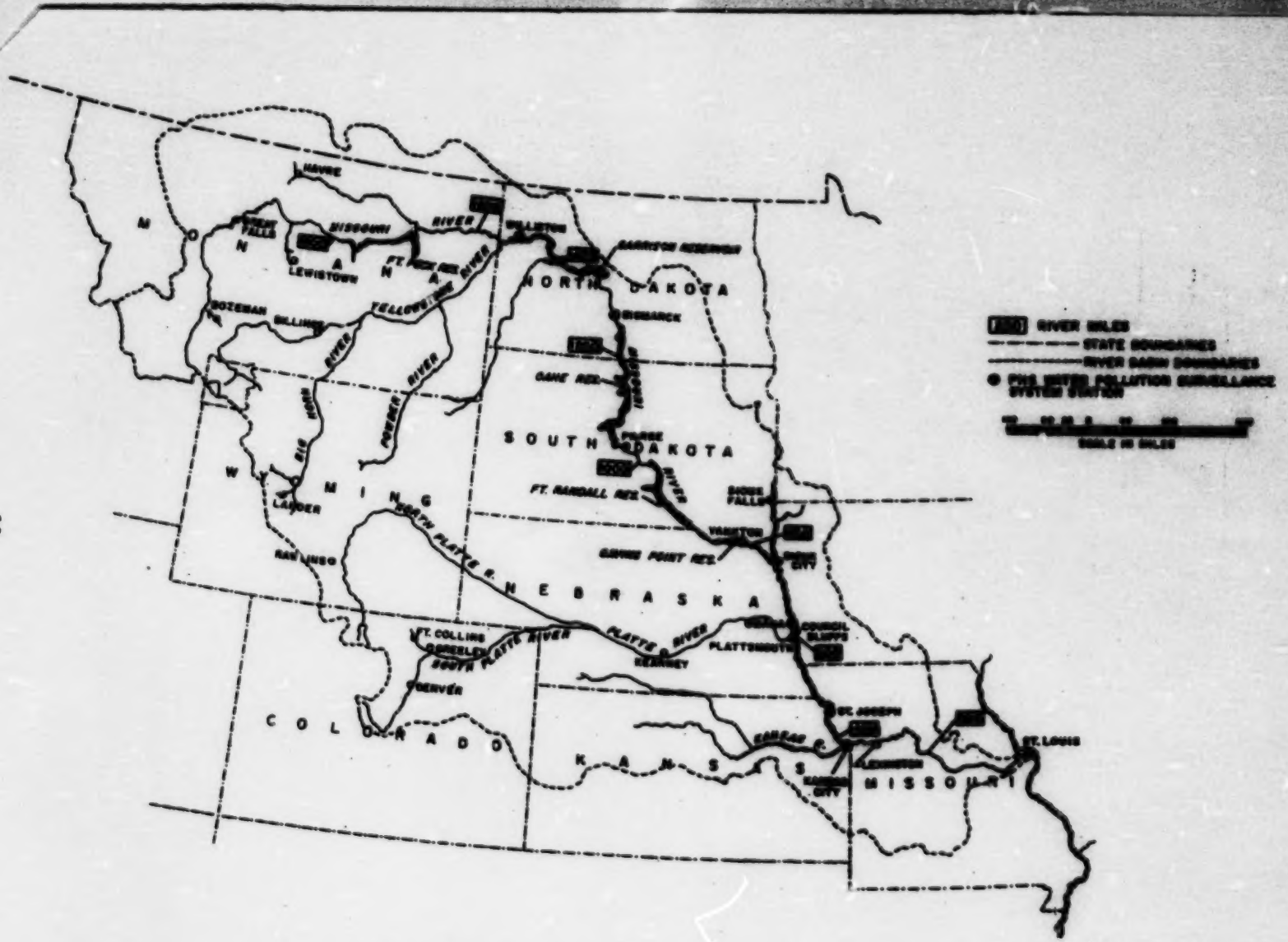
It is apparent that the sampling points are favorably located so that minimum effects of waste discharges are shown. These effects are, however, those which establish treatment requirements for waters taken from the river upstream from the respective cities. Pollution below the cities is, of course, much more severe.

CHAPTER II. HYDROLOGY

The Missouri River is formed by the confluence of the Jefferson, Madison and Gallatin Rivers in southwestern Montana at the town of Three Forks and flows 2,464 miles to its confluence with the Mississippi River at St. Louis, Missouri. The drainage area of 529,000 square miles is shown on Figure 1. Elevations range from 380 feet at St, Louis to 14,431 feet at Mt, Elbert in Colorado.

Average annual precipitation in the basin varies from less than 10 inches per year in Wyoming to about 40 inches per year at St. Louis. Average air temperatures vary from 60° to 80°F. in July and 5° to 30°F. in January. Mean maximum temperatures are generally 100°F. or more and minimums vary from -10° to -40°F. Annual evaporation rates range from about 25 inches in the northern mountains to about 60 inches in the southern plains. Net runoff increases from about one inch per year in the Great Plains to 20 inches per year in some mountainous areas.

The river is regulated by the multi-purpose dams and reservoirs above Yankton listed in Table 2. The stabilizing effects of this regulation upon the flow regimen are shown on Figure 2. At Williston, where about half the flow is regulated at Fort Peck Dam, average monthly flows varied within a factor of four throughout the year. Smaller variations occurred at Bismarck and Yankton where the flows are completely regulated. Below Yankton, the variability increases with distance downstream and in accordance with navigation requirements.



MISSOURI RIVER STUDY

MISSOURI RIVER DRAINAGE BASIN

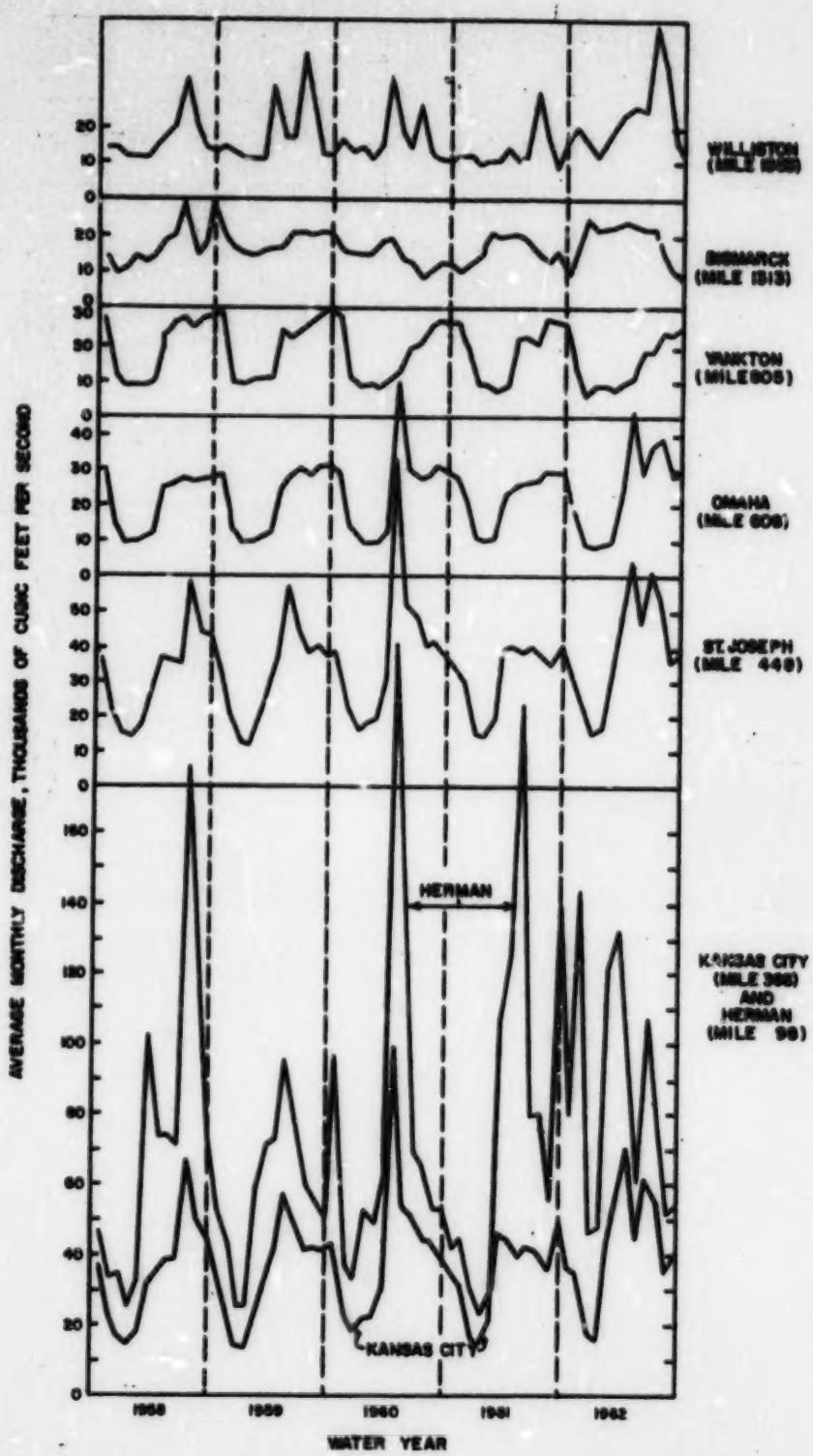
FIGURE 1

Table 2

MISSOURI RIVER RESERVOIRS

	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavin's Point
Mile	1690(a)	1399	1072	985(a)	880	811
Capacity, millions of acre-feet	19.4	245	23.6	1.9	6.1	0.5
Average length, miles	180	218	244	75	128	185
Average depth at dam, feet	200	164	188	65	118	47
Average pool elevation, feet	2230	1829	1603	1410	1348	1207
Date of Closure	June 1937	Dec. 1953	Aug. 1958	(b)	Aug. 1952	Aug. 1955

(a) Estimated
(b) Under Construction



MISSOURI RIVER STUDY

FLOWS, 1958-1962

FIGURE 2

Average annual flows and other hydrographic features at or near PHS Water Pollution Surveillance System stations are listed on Table 3. Flows at St. Louis are considered essentially equal to those at Hermann. Annual flows at the seven Missouri River stations during water years 1958 through 1962 averaged 87% of the long-term means. The calculation of this average allowed for the partial filling of Oahe Reservoir. Of the 13% flow deficiency, about half is probably due to evaporation in reservoirs.

Oahe Reservoir was closed after the sampling program had been in operation about one year, and the reservoir is still being filled. The water quality, particularly in the upper reach, is changing accordingly and may be expected to show additional variations as the reservoir system becomes filled to capacity and stabilized.

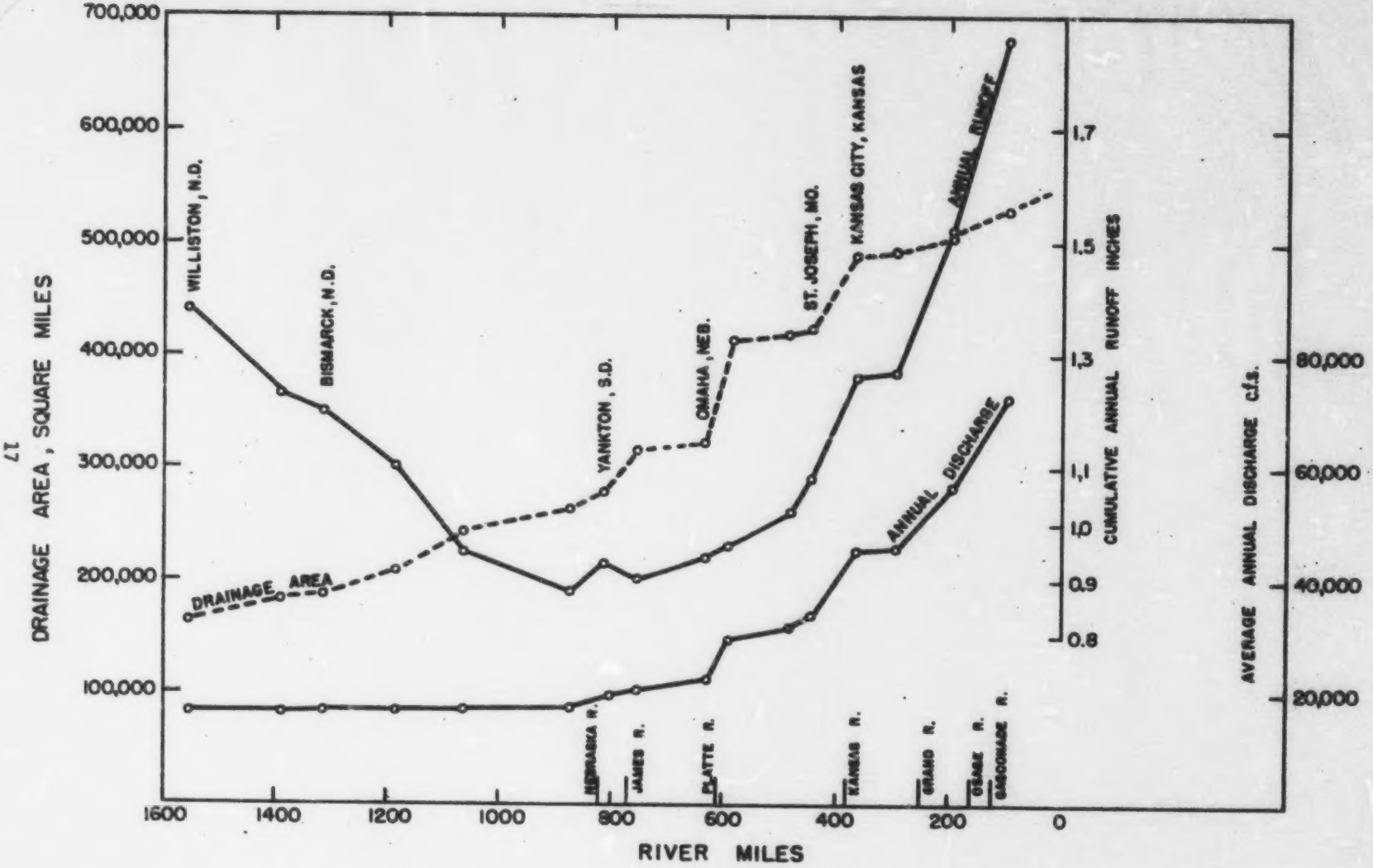
A hydrologic profile of the river between Williston and St. Louis showing average annual discharges during the period 1958-1961 and cumulative drainage areas and runoff at various points is shown on Figure 3. The average water surface profile and travel time for water year 1961 is shown on Figure 4.

Table 3

FLOW GAGING ON MISSOURI RIVER (a)

National Water Quality	Williston, N. Dakota	Bismarck, N. Dakota	Yankton, S. Dakota	Omaha, Nebraska	St.Joseph, Missouri	Kansas City, Missouri	St.Louis, Missouri
Location of USGS Gaging Station	"	"	"	"	"	"	Hermann, Missouri
Miles above mouth gaging station	1,553	1,313	805	608(c)	448	366	98
Drainage area (square miles)	164,500	186,400	279,500	322,800	424,300	429,310	528,000
Mean annual discharge (cfs)	22,140(b)	20,680	25,030	28,110	37,000	37,460	79,490
Maximum daily flow (cfs)	231,000 4/4/30	500,000 4/4/1872	480,000 4/13/52	396,000 4/18/52	370,000 4/29/1881	450,000(c)	892,000 6/1844
Minimum daily flow (cfs)	1,320 12/28/39	1,800 1/3/40	2,700 11/15,16/40	2,200 1/6/37	2,300 1/9/37	1,200(c)	4,200 1/10,12/40
Length of record, years to 1961	64;18(b)	33	31	33	33	45	64

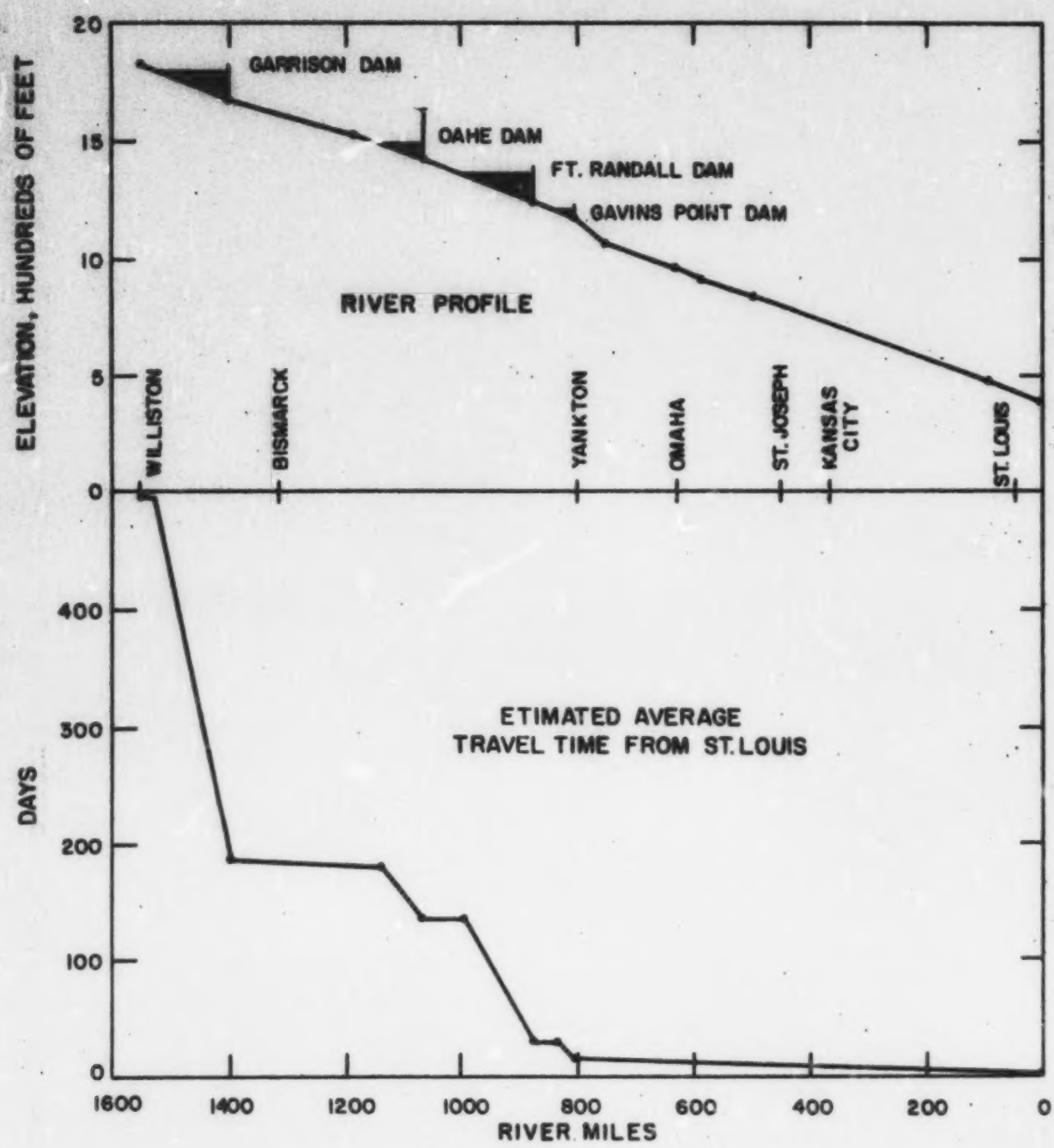
(a) Reference USGS State Surface Water Records for Water Year 1961.
(b) After reaching operational level in Fort Peck Dam (1943-1961).
(c) Estimated



MISSOURI RIVER STUDY

HYDROLOGIC PROFILE 1958-1961

FIGURE 3



MISSOURI RIVER STUDY

HYDROGRAPHIC PROFILE 1961

FIGURE 4

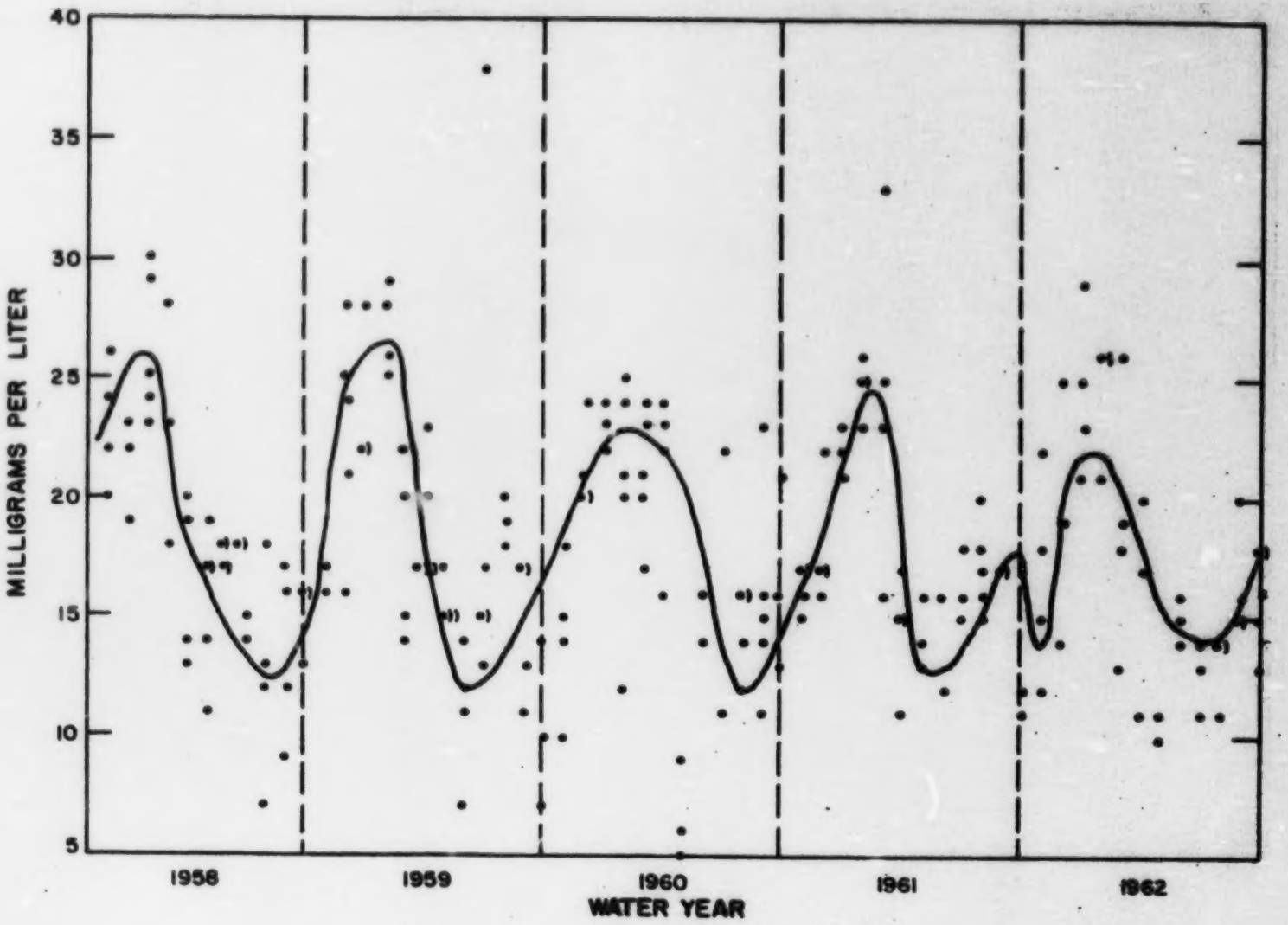
CHAPTER III. PHYSICAL AND CHEMICAL QUALITY

Concentrations of conservative* constituents in unregulated streams are generally inversely proportional to flow. This relationship implies that weathering, leaching, and removal take place at uniform rates; over sufficiently long periods, this approximation holds. Over shorter periods, seasonal variation in precipitation and temperature become more important. Since the Missouri River is regulated with large impoundments, the inverse flow-concentration relationship is obscured or destroyed at particular stations, depending upon the proportion of regulated flow.

Concentrations of non-conservative* constituents are a function of temperature, which may itself be considered non-conservative, and metabolic activities of stream life.

It has been noted earlier that this report is largely based upon subjective analysis of time series. Figure 5 shows a typical case, chlorides at Kansas City. A smooth curve was fitted by eye, compared with like curves for other constituents at Kansas City and chlorides at other stations (Figure 6), and adjusted as necessary to provide consistency. Comparison of Figure 6 with Figure 2 clearly shows the lack of a flow-concentration relationship in the upper regulated portion of the river. At or below Omaha the typical inverse relationship begins to develop. Figures

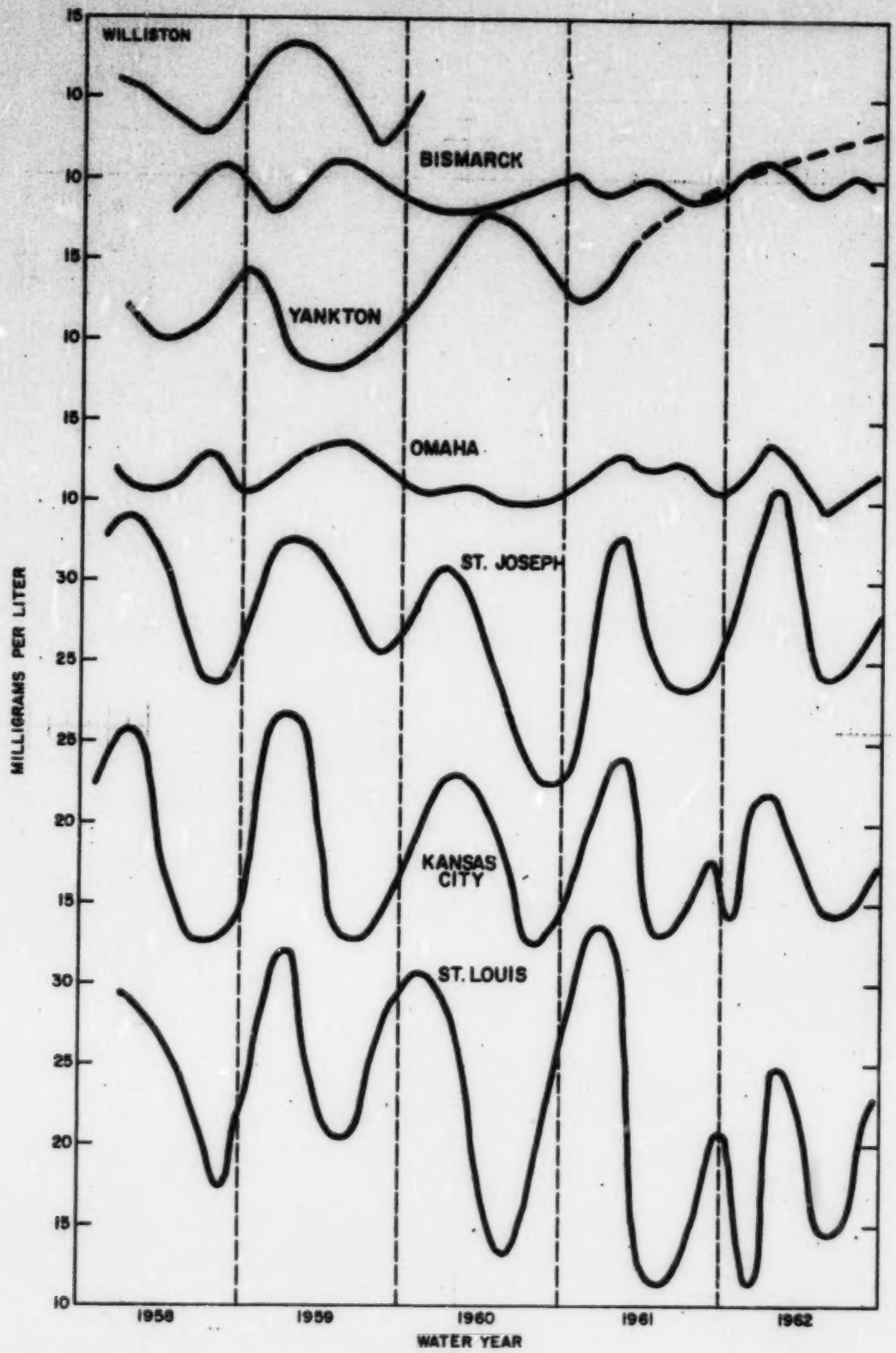
*Conservative constituents, e.g., chloride, are those which are not measurably affected by biological activity. Concentrations of non-conservative constituents such as nitrogen compounds or oxygen are affected by plant or animal life and frequently vary rapidly within a particular mass of water.



MISSOURI RIVER STUDY

CHLORIDE AT KANSAS CITY

FIGURE 5



MISSOURI RIVER STUDY
CHLORIDE
1958-1962
FIGURE 6

6 and 2 also show that the usual annual cycle of minimum chlorides during late spring or early summer and maximum chlorides during the winter was disturbed at Kansas City and St. Louis in water year 1962 by unusually heavy fall rains. Other conservative constituents were similarly affected.

From the smoothed curves, average ranges of the various parameters were determined and tabulated. For example, Figure 5 shows that average chloride concentrations at Kansas City varied from a late fall maximum of 26 mg/l to an early summer minimum of 12 mg/l in water year 1958. These are presented below with such remarks as are warranted. Extreme values for the five-year period are also listed.

For individual stations where the data clearly indicated trends in concentrations over the five-year period, appropriate notations in the tables and comments are included in the following paragraphs. At the remaining stations, actually the majority of cases, concentrations varied in such a way that they are assumed to be remaining essentially constant and no comments are presented.

Temperature

Table 4 shows increasing temperatures as the river flowed southward. The cause of higher temperatures at Williston, as compared with Bismarck, was probably due to the former station being in pool above Garrison Dam. This would facilitate heating of shallower waters.

Dissolved Oxygen

Concentrations and percentage saturation values of dissolved oxygen are listed on Table 5. The percentage saturation values were computed from quarterly averages of concentrations and temperatures, and thus can-

Table 4

WATER TEMPERATURE IN MISSOURI RIVER

Water Year	Average Range, °C 1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Williston-Max	20	22	21	24	22	*	26.0	0.0
Min	1	0.5	--	1	0			
Bismarck-Max	18	20	19	18	20	*	21.2	0.0
Min	0	0.5	0.5	0.5	0.5			
Yankton-Max	26	27	24	25	25	*	26.8	0.1
Min	2	2	1	2	2			
Omaha-Max	27	26	25	25	25	*	27.8	0.1
Min	1	0.5	0.5	0	0			
St. Joseph-Max	25	26	25	25	26	*	27.2	0.0
Min	1	1	1	1	1			
Kansas City-Max	25	27	26	26	27	*	28.3	0.0
Min	--	0	0	0	0			
St. Louis-Max	26	26	26	28	27	*	28.9	0.6
Min	2	3	1	3	2			

*None Detected

Table 5

DISSOLVED OXYGEN IN MISSOURI RIVER

Water Year	Average Range 1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Milligrams per liter								
Williston-Max	----	----	----	----	15.0	*	15.0	6.5
Min	----	----	----	----	9.0			
Bismarck-Max	----	13.0	13.4	13.4	13.0	*	13.7	7.9
Min	8.4	8.6	8.5	8.6	----			
Yankton-Max	14.2	14.8	13.6	14.8	17.0	increased	19.2	6.7
Min	8.4	7.2	7.4	8.6	8.6			
Omaha-Max	13.8	12.8	12.8	12.4	12.3	decreased	15.2	4.0
Min	7.4	5.8	6.2	6.2	5.5			
St. Joseph-Max	----	12.6	12.6	12.8	11.0	*	13.8	5.0
Min	6.0	6.6	5.4	6.6	5.8			
Kansas City-Max	----	11.4	12.4	12.6	11.8	*	13.2	3.2
Min	5.0	5.6	5.6	5.5	5.0			
St. Louis-Max	12.8	12.6	13.0	12.8	12.8	*	13.8	4.0
Min	4.6	6.0	6.2	6.4	6.2			
Percent Saturation (quarterly means)								
Williston-Max	----	----	----	----	129	*	----	---
Min	----	----	----	----	71			
Bismarck-Max	----	101	93	97	95	*	----	---
Min	85	87	88	89	88			
Yankton-Max	94	101	98	122	115	increased	----	---
Min	75	87	92	102	100			
Omaha-Max	92	90	83	84	86	decreased	----	---
Min	84	76	74	73	72			
St. Joseph-Max	----	93	94	85	76	decreased	----	---
Min	72	75	73	77	71	1960-62		
Kansas City-Max	----	82	87	86	80	*	----	---
Min	64	68	64	67	68			
St. Louis-Max	92	93	90	88	90	*	----	---
Min	74	80	75	77	79			

*None Detected

not be compared in detail with other parameters. Presence or absence of trends, however, can be shown.

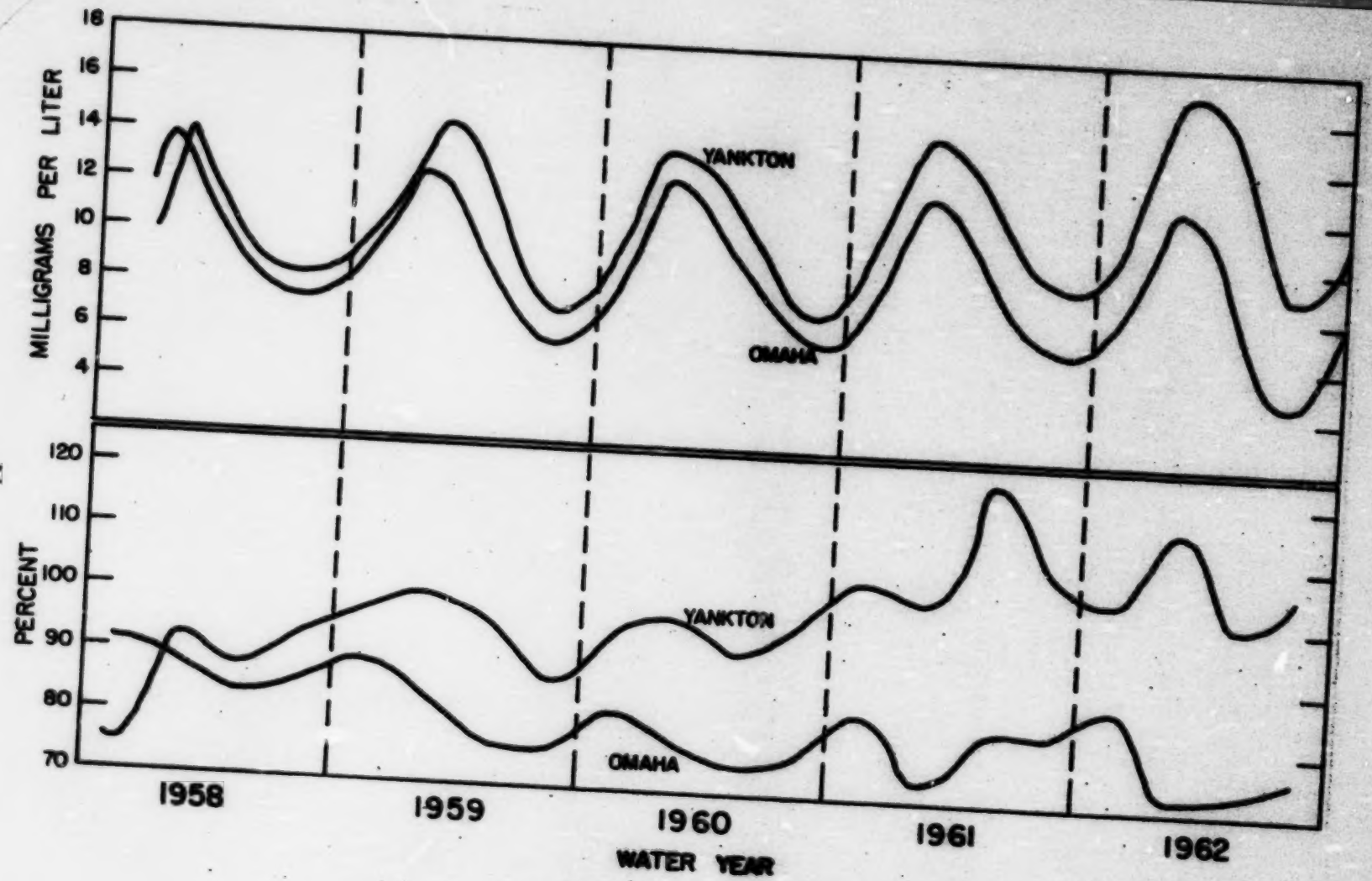
Dissolved oxygen concentrations followed an annual cycle with maxima during winter and minima in summer; this is to be expected from temperature variations. Percent saturation followed a generally similar pattern except that maxima and minima tended to precede the concentration extremes.

Oxygen levels in the lower reach, particularly at Kansas City, reflected waste discharges. Diurnal variations in dissolved oxygen are such that the tabulated minimum values, which are based on daytime observations, are almost certainly too high so that discussion of these values in terms of fish requirements would be unrealistic. Maxima, however, are considered valid. However, even these values are derived from favorably located sampling stations and are necessarily higher than concentrations of dissolved oxygen found downstream from the cities.

Two of the stations showed trends over the five-year period. The data are shown on Figure 7. Dissolved oxygen at Yankton was higher than at any other station on the river and increased during the five-year period. This is consistent with the plankton observations, particularly diatoms, which will be discussed in a subsequent chapter.

At Omaha there was a decreasing trend. While this was associated with an increase in COD, no such relationship was found at St. Louis which showed a somewhat similar COD increase.

The data did not disclose the relationships between the dissolved oxygen and short-term variations in plankton or BOD. The trends that were noted were far more apparent from the saturation values than from concentrations.



MISSOURI RIVER STUDY

CONCENTRATION AND PERCENT SATURATION OF DISSOLVED OXYGEN AT YANKTON AND OMAHA

FIGURE 7

Biochemical Oxygen Demand

BOD (5-day, 20°C.) concentrations were generally from a few tenths to a few milligrams per liter, with higher values in the lower reach, particularly at Kansas City, which reflected municipal and industrial waste dischargea. There were no apparent trends.

A marked seasonal pattern was found at and below Yankton with minima generally in late summer or early fall and maxima in late fall or spring. These are shown on Figure 8.

Chemical Oxygen Demand

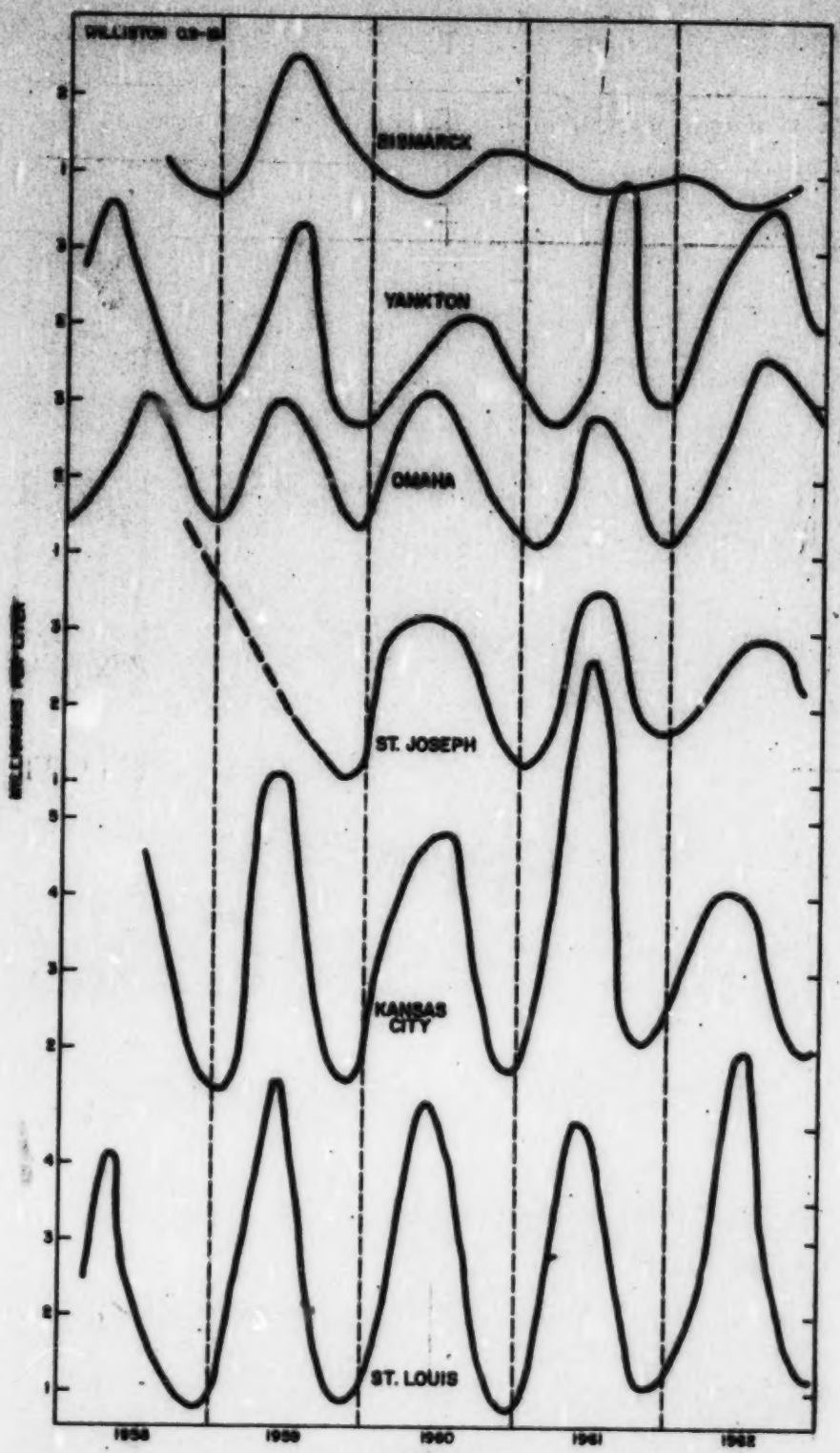
COD concentrations varied randomly in the upper reach of the river. There were general increases at Omaha and St. Louis and no obvious trend at Kansas City; these stations also exhibited minima in fall or winter and maxima in spring and summer. These variations, which are shown on Figure 9, tended to lag extremes in BOD by about three months.

Concentration ranges were Williston, 9 to 58; Bismarck, 3 to 9; Yankton, 5 to 37; Omaha, 1 to 198; St. Joseph, 7 to 89; Kansas City, 4 to 274; and St. Louis, 4 to 143 mg/l.

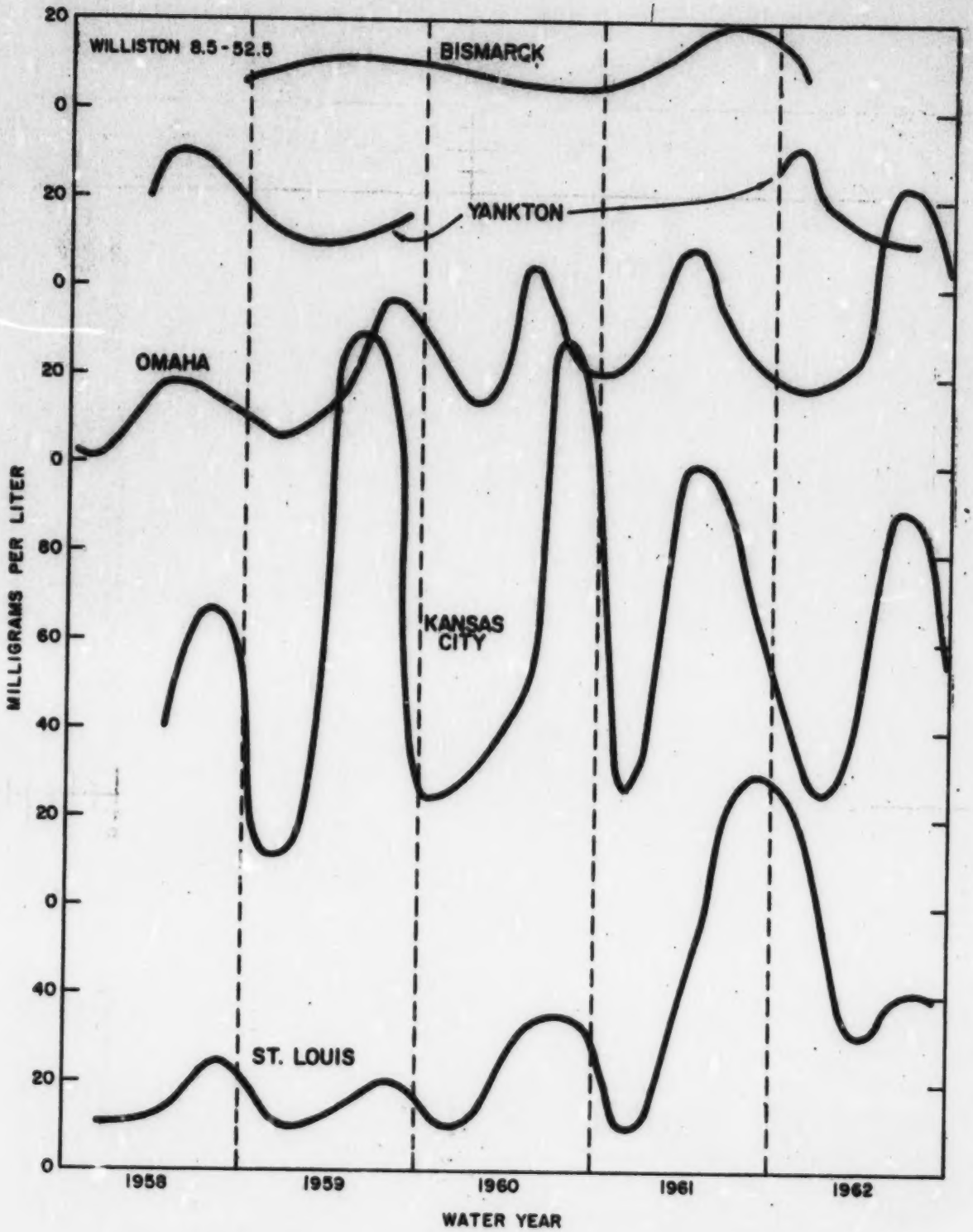
Chlorine Demand

The 24-hour chlorine demand varied in a more or less regular pattern at and below Yankton, as shown on Figure 10. Minima and maxima generally occurred in the fall and spring, respectively. These times were somewhat similar to those for COD, although the trends of the two parameters were dissimilar.

The time variations of the 1 and 24-hour chlorine demand were similar. However, the numerical relationships between the two and be-



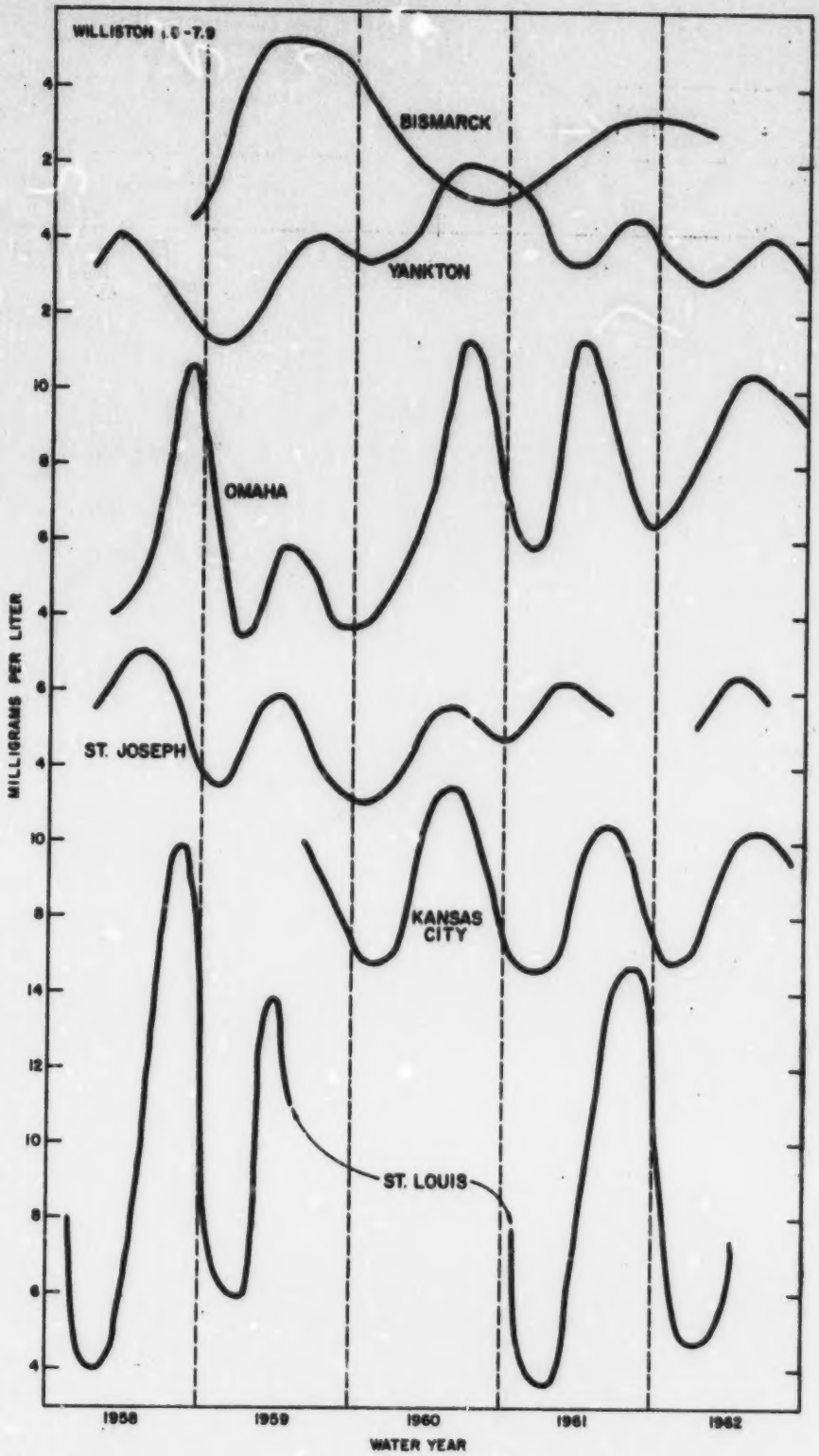
MISSOURI RIVER STUDY
BIOCHEMICAL OXYGEN DEMAND
1958 – 1962
FIGURE 8



MISSOURI RIVER STUDY

CHEMICAL OXYGEN DEMAND
1958 - 1962

FIGURE 9



MISSOURI RIVER STUDY
24-HR. CHLORINE DEMAND
1958 - 1962
FIGURE 10

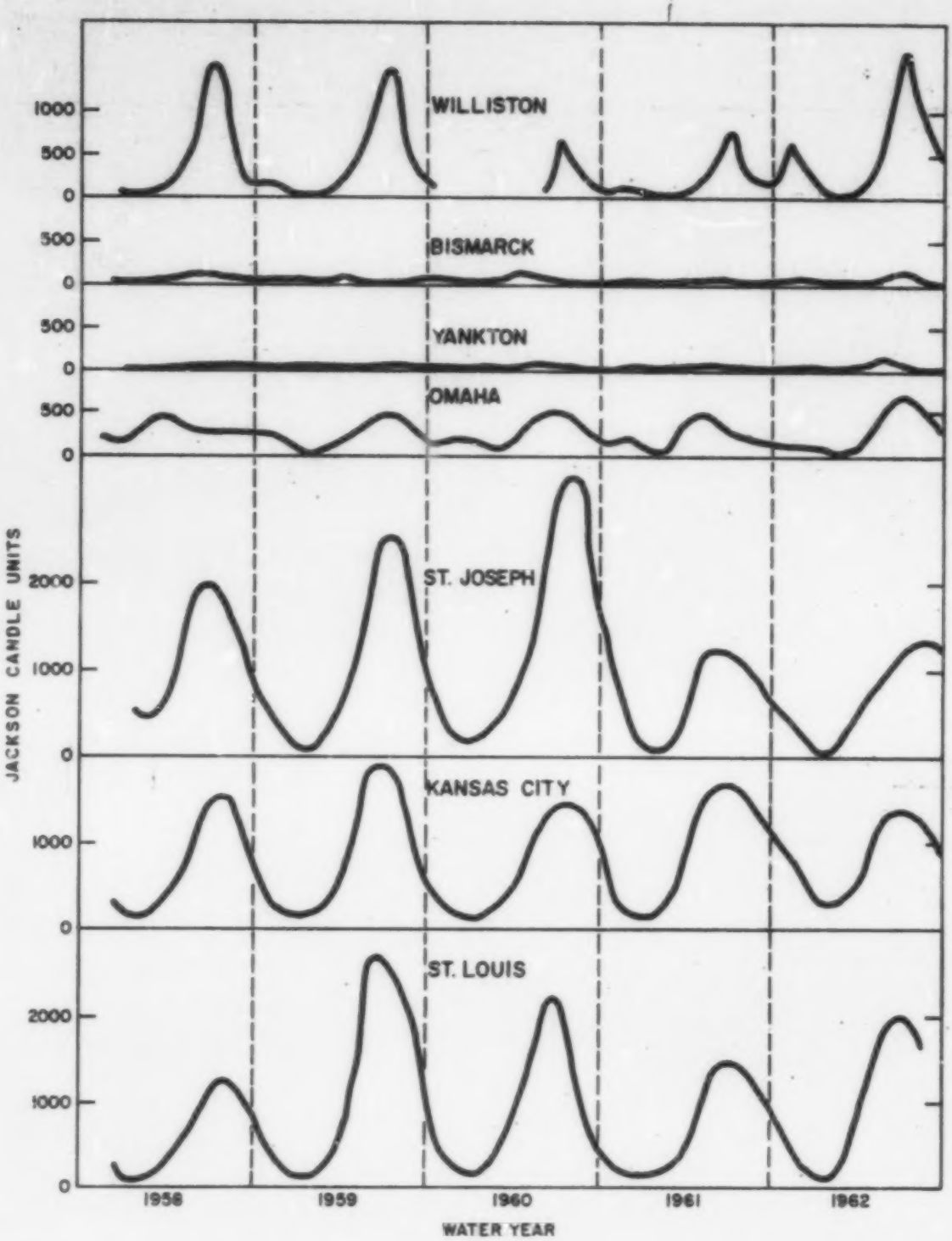
tween the 1-hour demand and other related parameters were highly variable. Concentrations of 24-hour chlorine demand in mg/l varied from 1.7 to 8.3 at Williston, 0.2 to 9.2 at Bismarck, 0.9 to 7.0 at Yankton, 2.2 to 28.5 at Omaha, 3.0 to 8.5 at St. Joseph, 3.8 to 18.2 at Kansas City, and 3.0 to 20.9 at St. Louis.

Turbidity

Average turbidities in the Missouri River are shown in Figure 11. The effects of regulation are evidenced by the low values at Bismarck and Yankton. Below Yankton turbidity increased by an order of magnitude at Omaha, and an additional three- or four-fold throughout the lower reaches.

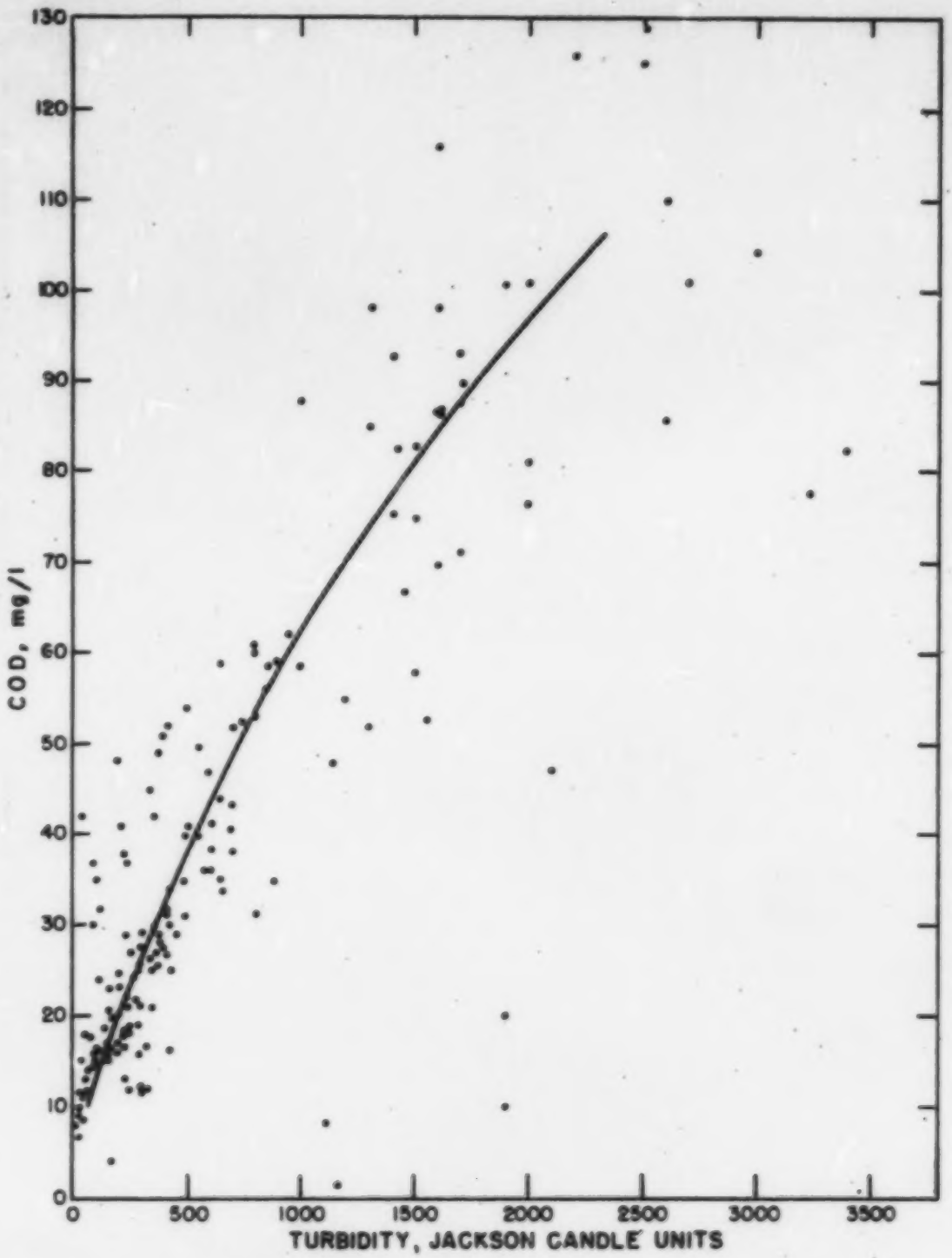
The interrelationship between COD and turbidity shown for Kansas City on Figure 12 suggests that, in the lower reaches, a significant amount of organic material is associated with silt carried to the river. Since the high COD's and turbidities were associated with low BOD's, such organic material must be relatively resistant to biochemical degradation. Similar relationships at St. Louis are shown on Figure 13, although a much greater scatter and a different proportionality constant are suggested. A more exact description and evaluation of this phenomenon, which may be significant in carbon filter and other sampling methods for organic materials, requires additional investigation, including determination of the concentrations, percent volatiles, and grain-size distribution of suspended solids.

Turbidity ranges, in Jackson candle units, were from less than 25 at all stations to maxima of 3,000 at Williston, 310 at Bismarck, 400 at Yankton, 6,000 at Omaha, 12,000 at St. Joseph, 6,500 at Kansas City, and 4,500 at St. Louis.



MISSOURI RIVER STUDY
TURBIDITY
1958 - 1962

FIGURE 11

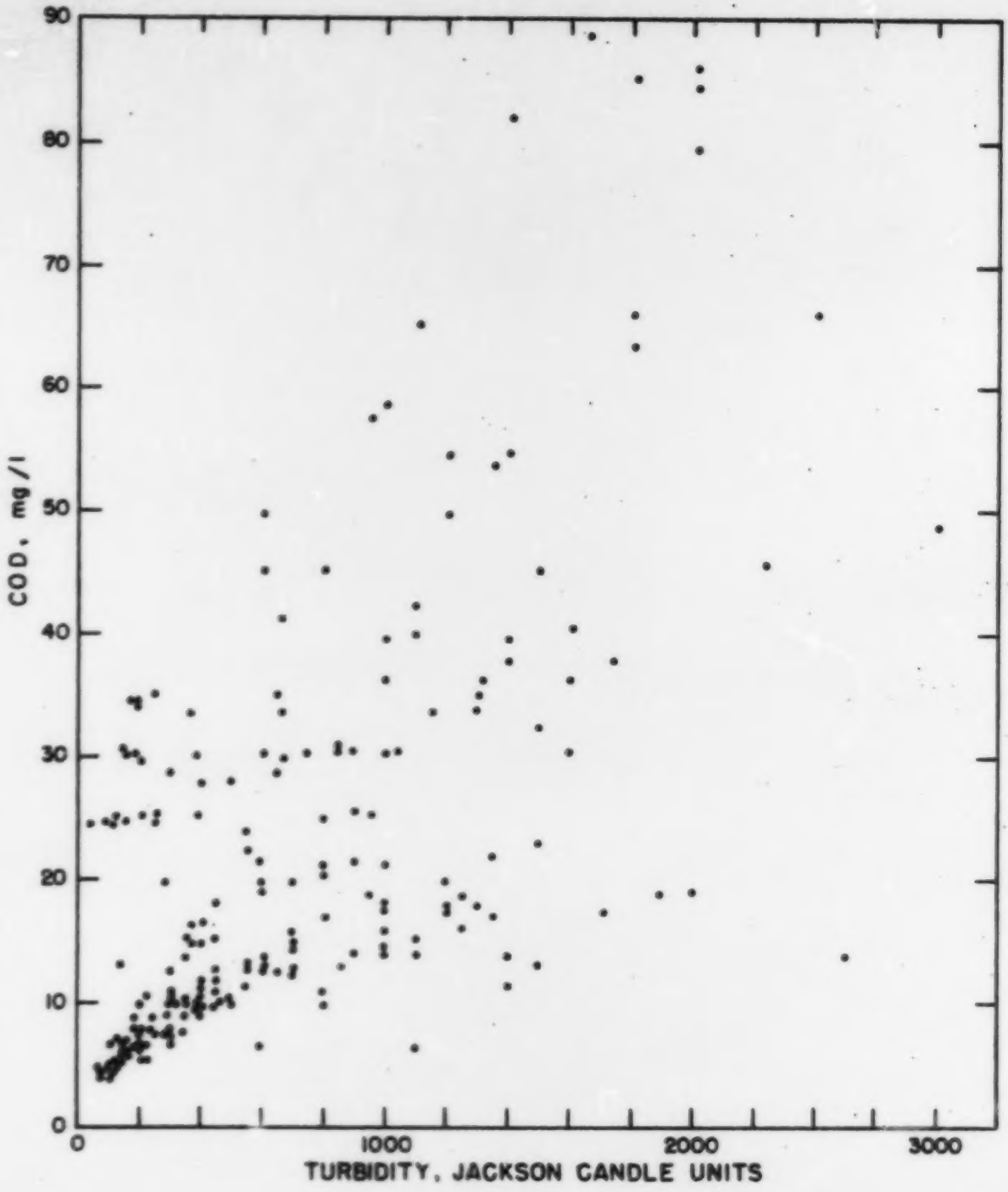


MISSOURI RIVER STUDY

COD - TURBIDITY RELATIONSHIP AT KANSAS CITY

1958 - 1962

FIGURE 12



MISSOURI RIVER STUDY

COD - TURBIDITY RELATIONSHIP AT ST. LOUIS
1958 - 1962

FIGURE 13

Color

Seasonal variations in color occurred in the same manner as turbidity. Average and extreme values are listed in Table 6. It should be noted that the highest absolute values for color were found at Yankton where turbidities were minimal; this color is presumably related to the high biological activity in upstream reservoirs.

pH

The Missouri River is, as are most surface waters, slightly alkaline. No systematic variations in pH values were found. Values ranged from 7.9 to 8.6 at Williston, 7.9 to 8.5 at Bismarck, 7.8 to 8.5 at Yankton, 7.7 to 8.5 at Omaha, 7.1 to 8.7 at St. Joseph, 7.5 to 8.1 at Kansas City, and 7.8 to 8.7 at St. Louis.

Sodium

Sodium is determined twice yearly from composited samples. Minimum, average, and maximum concentrations in mg/l for the various stations were: Williston 44, 55, 62; Bismarck 50, 57, 77; Yankton 48, 56, 65; Omaha 28, 58, 68; St. Joseph 28, 46, 62; Kansas City 23, 40, 59; and St. Louis 22, 29, 40. The relatively wide range of concentrations accords with similarly wide ranges for sulfate and alkalinity.

Potassium

Potassium is also determined semi-annually. Average concentrations increased from 4.0 mg/l at Williston to 6.1 mg/l at Kansas City and then dropped to 5.3 mg/l at St. Louis. Corresponding ranges were 3.0 to 4.7, 5.5 to 8.4, and 4.1 to 7.1 mg/l, respectively.

Table 6

COLOR IN MISSOURI RIVER

Average Range, Platinum Scale Units Water Year	1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Williston-Max	30	15	--	--	--	*	60	0
Min	5	2	--	--	--			
Bismarck-Max	25	16	16	20	--	*	110	0
Min	0	4	2	4	4			
Yankton-Max	55	55	60	40	36	*	140	5
Min	20	20	20	8	18			
Omaha-Max	6	7	24	24	15	*	40	2
Min	--	4	6	7	5			
St. Joseph-Max	--	30	16	16	10	*	50	0
Min	12	10	10	2	2			
Kansas City-Max	21	26	27	19	10	*	50	1
Min	10	8	12	4	3			
St. Louis-Max	24	25	27	27	29	*	58	9
Min	11	12	14	11	16			

*None Detected

Chloride

Figures 5 and 6 show variations and levels of chlorides in the Missouri River. These are summarized in Table 7. The higher values in the lower reach show the effect of the Platte and Kansas Rivers.

Sulfate

Sulfate generally decreased below Omaha. Occasional high values at St. Joseph showed the effects of the Platte River. Averages and ranges are listed on Table 8. On two occasions, once at Omaha and once at St. Joseph, sulfate concentrations exceeded the 1962 Public Health Service Drinking Water Standards; this event occurred less than 0.4% of the time.

Alkalinity

Table 9 shows that average concentrations and variability in alkalinity tended to increase downstream. There was a definite trend towards increasing alkalinity at all stations except Williston.

Hardness

Hardness showed increasing trends throughout most of the river. Table 10 indicates that overall longitudinal changes were minor. Most municipalities in the basin provide softening in order to correct the usual 150 to 300 mg/l hardness.

Total Dissolved Solids

Table 11 shows that TDS increased between Bismarck and Omaha and decreased thereafter. There was an increasing trend at Bismarck.

Table 7

CHLORIDE IN MISSOURI RIVER

Water Year	Average Range, mg/l 1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Williston-Max	--	13	--	--	--	*	13	5
Min	8	7	--	--	--			
Bismarck-Max	11	12	8	10	12	*	14	1
Min	--	6	6	6	8			
Yankton-Max	--	14	19	22	--	increased	25	7
Min	10	8	12	--	--			
Omaha-Max	13	14	11	13	14	*	18	5
Min	10	10	10	10	9			
St. Joseph-Max	34	33	31	33	36	*	48	15
Min	24	26	17	24	24			
Kansas City-Max	26	27	23	25	--	*	38	5
Min	12	12	12	13	--			
St. Louis-Max	--	33	31	33	--	*	43	5
Min	17	20	13	11	--			

*None Detected

Table 8

SULFATE IN MISSOURI RIVER

Water Year	Average Range, mg/l 1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Williston-Max	---	---	---	---	---	----	---	---
Min	---	---	---	---	---	----	---	---
Bismarck-Max	---	220	185	180	185	*	232	105
Min	---	170	165	155	170			
Yankton-Max	---	---	---	---	---	----	220	110
Min	---	---	---	---	---			
Omaha-Max	---	205	205	190	190	*	257	51
Min	170	165	160	135	150			
St. Joseph-Max	---	165	180	170	155	*	276	44
Min	105	100	85	100	75			
Kansas City-Max	150	185	170	170	---	*	229	49
Min	95	110	105	100	---			
St. Louis-Max	---	160	150	130	---	*	185	20
Min	50	75	40	50	---			

*None Detected

Table 9

ALKALINITY IN MISSOURI RIVER

Water Year	Average Range, mg/l 1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Williston-Max	175	195	---	175	170	*	200	70
Min	110	110	---	120	95			
Bismarck-Max	165	170	165	165	170	increased	228	108
Min	---	145	150	150	155			
Yankton-Max	160	170	170	180	180	increased	196	92
Min	140	150	140	150	140			
Omaha-Max	---	190	175	195	195	slight	236	90
Min	150	135	135	155	150	increase		
St. Joseph-Max	195	185	205	210	215	slight	280	94
Min	120	155	150	155	150	increase		
Kansas City-Max	180	195	200	205	210	increased	269	96
Min	120	150	145	145	160			
St. Louis-Max	180	200	195	215	---		278	79
Min	95	110	115	110	---	increased		

*None Detected

Table 10

HARDNESS IN MISSOURI RIVER

Water Year	Average Range, mg/l 1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Williston-Max	260	290	---	265	250	*	304	110
Min	150	145	---	160	160			
Bismarck-Max	215	250	225	225	240	increased	336	106
Min	180	200	190	210	215			
Yankton-Max	---	255	230	250	255	increased	266	136
Min	205	210	210	225	225			
Omaha-Max	250	250	245	265	275	increased	304	112
Min	210	220	230	225	245			
St. Joseph-Max	---	275	270	300	275	*	456	108
Min	175	190	200	210	175			
Kansas City-Max	270	260	270	260	290	increased	315	121
Min	170	190	200	190	200			
St. Louis-Max	240	270	260	275	---	slight	322	94
Min	125	160	150	150	---	increase		

*None Detected

Table 11

TOTAL DISSOLVED SOLIDS IN MISSOURI RIVER

Water Year	Average Range, mg/l 1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Williston-Max	---	---	---	---	---	----	---	---
Min	---	---	---	---	---			
Bismarck-Max	---	435	440	485	475	increased	621	268
Min	---	375	360	390	425			
Yankton-Max	---	---	---	---	---	----	530	270
Min	---	---	---	---	---			
Omaha-Max	550	530	515	525	525	decreased	590	174
Min	455	445	375	450	375			
St. Joseph-Max	480	580	480	510	480	*	660	196
Min	350	350	310	360	370			
Kansas City-Max	470	490	470	500	---	*	556	208
Min	330	360	370	350	---			
St. Louis-Max	---	450	---	470	---	*	566	144
Min	290	280	---	250	---			

*None Detected

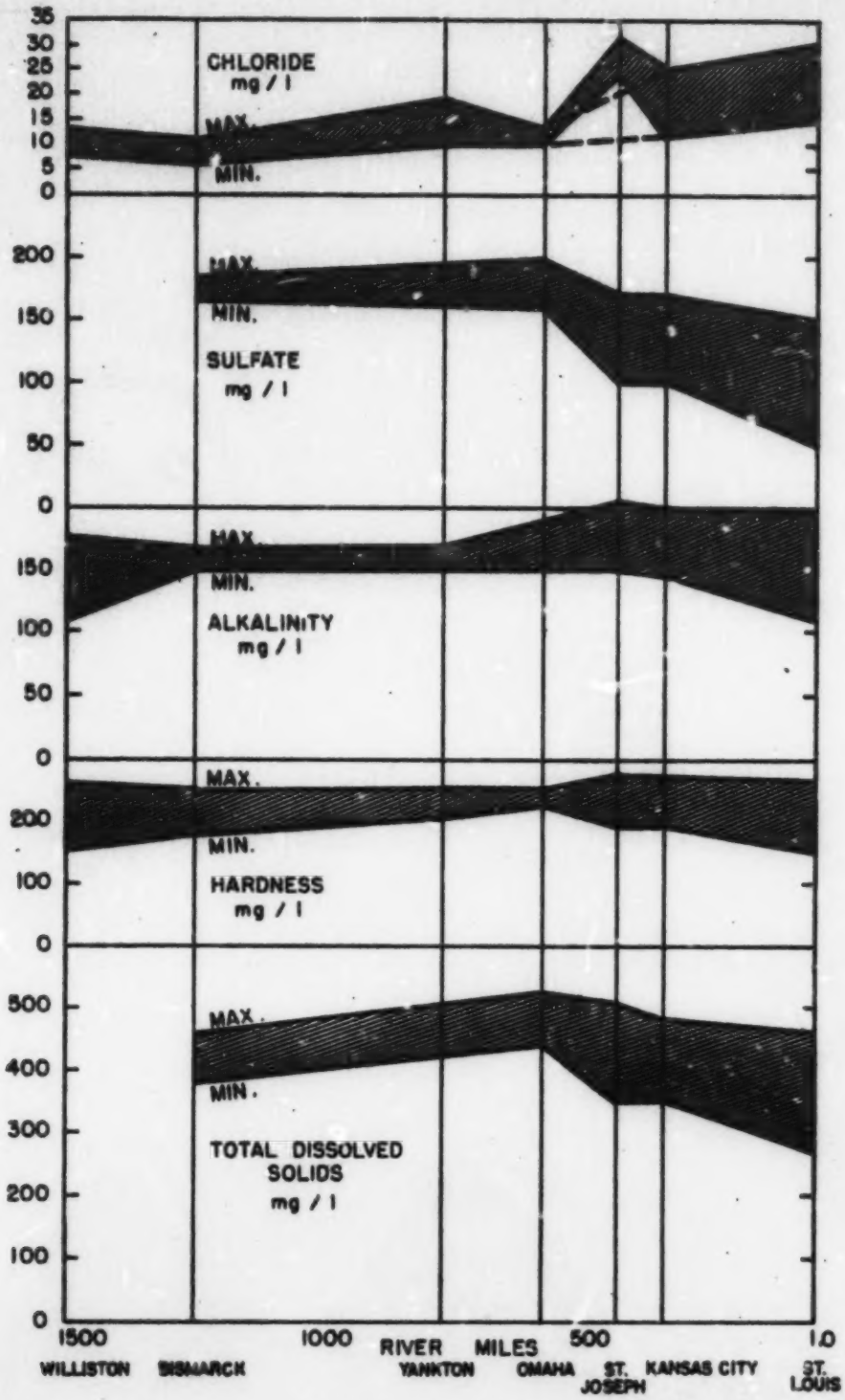
Longitudinal Variations in Major Constituents

The inverse relationship of flow and concentration of various constituents at individual stations has been previously mentioned. Regulation on the upper reach of the Missouri River overrides the usual flow-concentration relationships particularly at Bismarck, and water quality is a complex function of influent flows and quality, residence time, and mixing.

By the time the river reaches St. Louis, there is a partial dependence of water quality upon flow. Comparison of Figure 2 with Figure 5 and Tables 7 through 11 shows clearly that higher concentrations of major constituents are associated with lower flows. Here, average monthly flows generally vary by a factor of 5 or 6 during the year, while concentrations vary by a factor of 2 or 3. This means that the effects of regulation are still significant.

Figures 14 and 15 show average concentrations and annual transport, respectively, of major constituents. These indicate that reported chloride concentrations at St. Joseph are inconsistent with the annual chloride transport and estimated values have been interpolated. The reported values have resulted from incomplete mixing of a local discharge.

Chemical denudation or leaching rates for the several portions of the Missouri basin are shown in Figure 16. These rates are based upon average annual flows and water quality and are thus first approximations; they are, however, consistent with published data.[17] The incremental and accumulated rates reflect the rates of weathering and leaching of rocks and soils, agricultural practices, and, to a lesser and probably minor extent, the rates of municipal and industrial waste discharge.

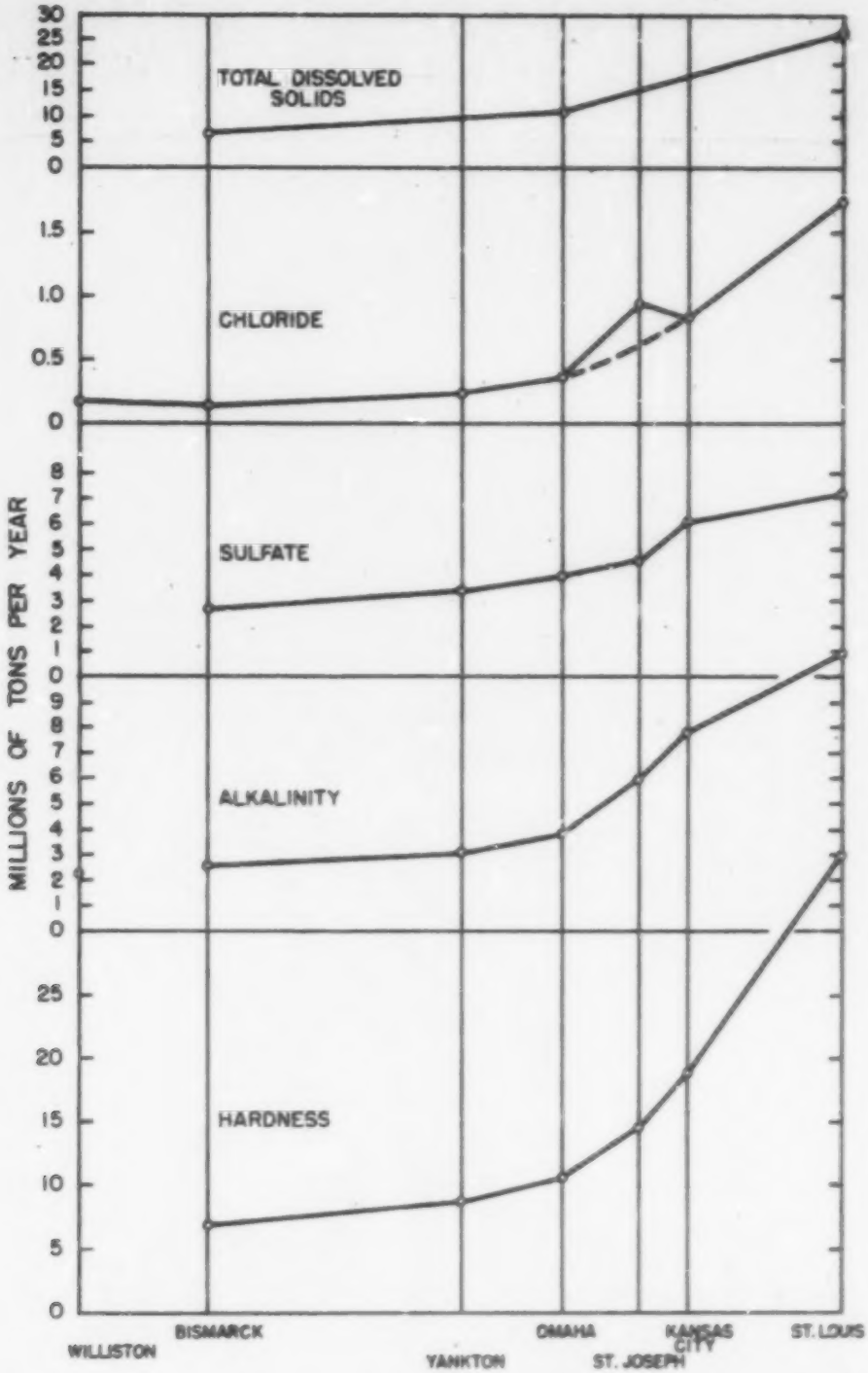


MISSOURI RIVER STUDY

LONGITUDINAL VARIATIONS IN MAJOR CONSTITUENTS

1958-1962

FIGURE 14

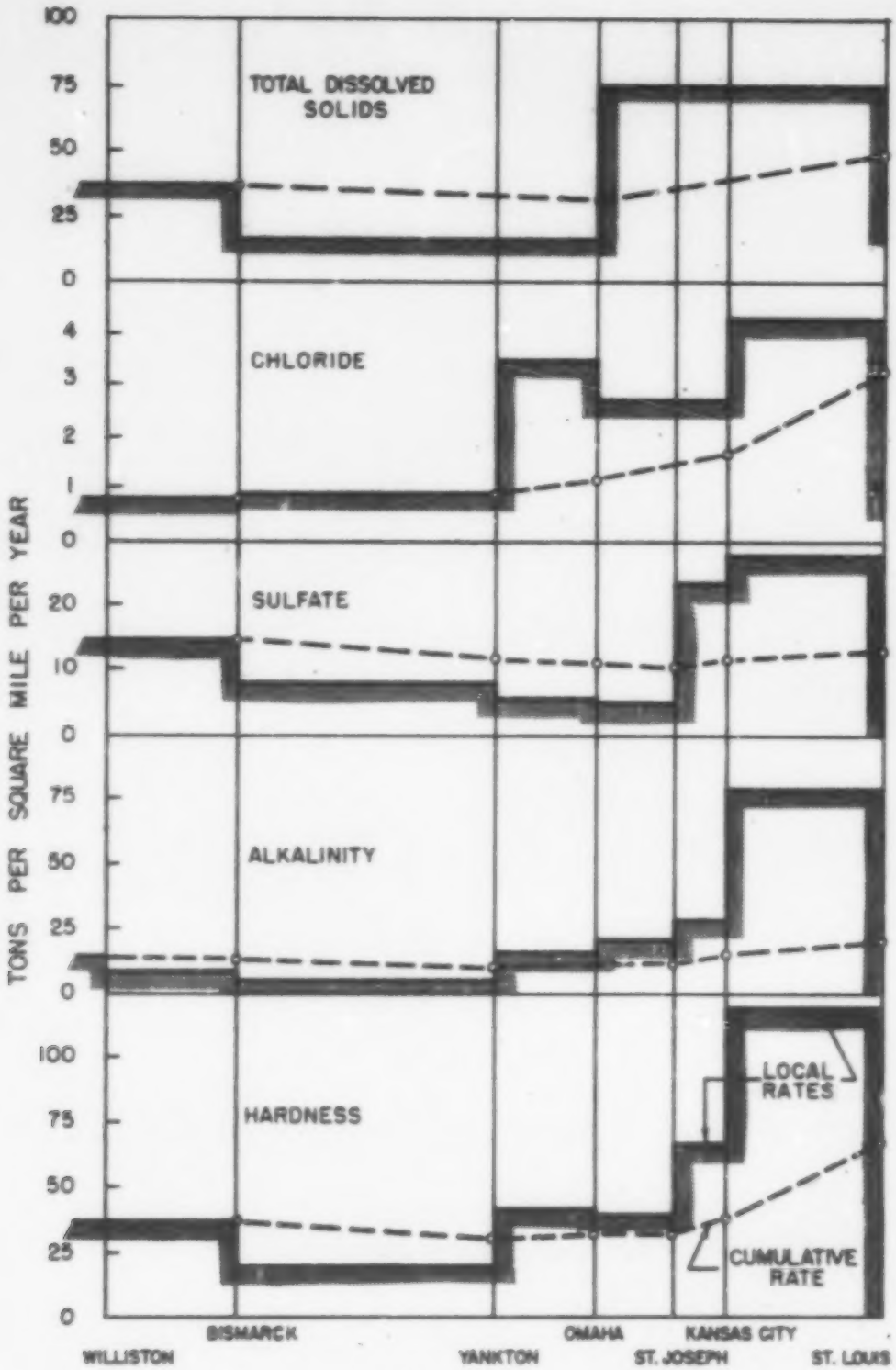


MISSOURI RIVER STUDY

AVERAGE ANNUAL TRANSPORT OF MAJOR CONSTITUENTS

1958 - 1962

FIGURE 15



MISSOURI RIVER STUDY

CHEMICAL DENUDATION OF MISSOURI BASIN, 1958-1962

FIGURE 16

United States Geological Survey Data

A comparison of chemical data reported by the U.S. Geological Survey with data reported by PHS participating laboratories was made. This enabled further study of the chloride concentrations at St. Joseph, as well as other constituents at stations where direct comparisons could be made. The only USGS data which have been reported to date (October 1963) and which can be compared with PHS data from the Missouri River are those found in Water Supply Paper 1572.[18] It is possible to compare five parameters at Williston and Yankton. An approximate comparison with St. Joseph is provided by data from the USGS Nebraska City station located about 100 miles upstream but which is about 30 miles below the last major tributary, the Platte River.

Results from the two programs are listed on Table 12. It might be expected that the discrete samples analyzed by the participating laboratories would show somewhat more variation than the composited samples of the USGS. Where possible, average ranges for PHS data are accordingly tabulated.

Values for alkalinity, hardness and sulfate are in reasonable agreement. Chloride data are comparable except for St. Joseph; this confirms the previous interpretation that the PHS station there is affected by a local, incompletely mixed, discharge.

The USGS observations of pH are systematically lower than those reported by the PHS. This is presumably due to the delays involved in the USGS compositing procedures; a similar bias was found when pH was determined on PHS samples shipped to the Cincinnati laboratories which had comparable delays between sampling and analysis.

Table 12

COMPARISON OF DATA FROM PHS WATER POLLUTION SURVEILLANCE SYSTEM AND FROM U.S. GEOLOGICAL SURVEY, 1958

		Williston		Yankton		St. Joseph[a]	
		WSQN	USGS	WSQN	USGS	WSQN	USGS
pH	Max	8.2	8.0	8.5	7.7	8.4	7.9
	Min	7.9	6.9	7.8	7.0	7.1	6.7
	Average Range	---	---	---	---	7.7-8.1	---
Sodium[b] mg/l	Max	62	74	65	71	62	69
	Min	60	22	60	44	46	29
	Average Range	--	55	--	60	--	54
Chloride mg/l	Max	12	13	15	12	48	24
	Min	7	2	8	7.7	20	18
	Average Range	8-12	--	--	--	24-34	--
Sulfate mg/l	Max	--	--	--	--	205	180
	Min	--	--	--	--	92	129
	Average Range	--	--	--	--	105-160	---
Alkalinity[c] mg/l	Max	188	200	160	164	214	193
	Min	90	111	128	133	105	110
	Average Range	110-175	---	135-155	---	120-195	---
Hardness mg/l	Max	290	304	260	236	282	264
	Min	114	139	184	194	140	141
	Average Range	145-260	---	---	---	175-265	---

Note: (a) USGS station at Nebraska City, Nebraska, (b) PHS data are for two composited samples collected in 1959, (c) USGS alkalinity data are reported in WSP 1572 as ppm HCO_3. These were converted to $CaCO_3$ by multiplying by 0.82.

Ammonia Nitrogen

Variations and usual ranges of NH_3-N are listed in Table 13. In general, minimum values occurred in late summer and early fall, and maxima in the spring. NH_3-N increased along with COD at Omaha, although the available data do not show whether the two are related. Concentrations could not be correlated with plankton populations, possibly because only a fraction of the total nitrogen was measured.

Minor Constituents

Concentrations of minor constituents are summarized in Table 14. Most of these elements were never present in significant quantities.

The maximum barium concentration was less than half the Public Health Service Drinking Water Standards. Boron concentrations were well under limiting values for irrigation water for sensitive plants. Copper concentrations varied by more than two orders of magnitude at some stations; although the reported values were still less than the Drinking Water Standards, the large variability indicates the need for analyzing discrete samples.

One sample from Omaha contained almost twice the Drinking Water Standard value for iron, and manganese exceeded the standard once at Bismarck.

Fluoride concentrations approached but did not exceed the Drinking Water Standards for the climate of the Missouri Valley.

Table 13

AMMONIA NITROGEN IN MISSOURI RIVER

Water Year	Average Range, mg/l 1958	1959	1960	1961	1962	Trend	Extremes Max	Min
Williston-Max	---	---	---	---	---	----	0.2	0.0
Min	---	---	---	---	---			
Bismarck-Max	---	---	---	0.2	0.3	*	0.6	0.0
Min	---	---	0.1	0.1	0.2			
Yankton-Max	0.2	0.2	0.2	0.2	0.2	*	0.4	0.0
Min	0.1	0.1	0.1	0.1	0.1			
Omaha-Max	0.3	0.3	0.3	0.5	0.7	increased	1.6	0.0
Min	0.0	0.0	0.0	0.0	0.0			
St. Joseph-Max	0.4	0.4	0.3	0.5	0.5	*	2.0	0.0
Min	0.0	0.0	0.0	0.0	0.0			
Kansas City-Max	---	0.5	0.5	0.5	0.5	*	1.6	0.0
Min	---	0.0	0.0	0.0	0.0			
St. Louis-Max	0.4	0.5	---	0.5	0.4	*	0.5	0.0
Min	0.0	0.0	0.0	0.0	0.0			

*None Detected

Table 14

MINOR CONSTITUENTS IN MISSOURI RIVER
(Micrograms per liter)

	1962 Drinking Water Standard		Williston	Bismarck	Yankton	Omaha	St. Joseph	Kansas City	St. Louis
Antimony	-	Max.	<40	<40	<40	<30	<30	<30	<30
		Min.	-	-	-	-	-	-	-
		Avg.	-	-	-	-	-	-	-
Barium	1000	Max.	90	200	90	200	200	400	200
		Min.	<8	20	20	20	10	70	80
		Avg.	34	60	50	90	90	140	150
Beryllium	-	Max.	<2	<2	<2	<2	<2	<1	<1
		Min.	-	-	-	-	-	-	-
		Avg.	-	-	-	-	-	-	-
Bismuth	-	Max.	<10	<20	<20	<20	<20	<10	<10
		Min.	-	-	-	-	-	-	-
		Avg.	-	-	-	-	-	-	-
Boron	-	Max.	180	170	200	200	180	130	130
		Min.	80	60	80	30	80	60	60
		Avg.	130	130	150	130	130	110	80
Cadmium	10	Max.	<8	<10	<10	<20	<10	<7	<8
		Min.	-	-	-	-	-	-	-
		Avg.	-	-	-	-	-	-	-
Chromium	50	Max.	4	8	9	40	9	10	3
		Min.	<4	<4	<4	<4	<3	<3	<3
		Avg.	-	-	-	-	-	-	-
Cobalt	-	Max.	<8	<8	<8	<7	<7	<4	<5
		Min.	-	-	-	-	-	-	-
		Avg.	-	-	-	-	-	-	-
Copper	(1000)	Max.	10	300	300	30	300	30	10
		Min.	<1	20	4	<1	<1	4	1
		Avg.	4	90	96	9	33	18	7
Fluoride	800	Max.	800	730	710	730	600	700	630
		Min.	400	460	420	400	300	370	320
		Avg.	600	340	350	340	300	380	440
Iron	(300)	Max.	30	30	90	300	300	200	200
		Min.	9	<8	<8	20	10	10	10
		Avg.	20	70	30	120	60	70	110
Lead	50	Max.	<10	<20	90	<20	<20	<10	<10
		Min.	-	-	-	-	-	-	-
		Avg.	-	-	-	-	-	-	-
Manganese	(50)	Max.	<8	80	20	<10	<10	<8	<8
		Min.	-	<10	<10	-	-	-	-
		Avg.	-	-	-	-	-	-	-
Molybdenum	-	Max.	10	10	20	20	<8	30	10
		Min.	<8	8	<8	7	<8	<8	<8
		Avg.	-	9	10*	10*	13	10*	9*
Nickel	-	Max.	<8	<8	<8	9	20	<4	<5
		Min.	-	-	-	<7	<7	-	-
		Avg.	-	-	-	-	-	-	-
Selenium	10	Max.	<10	<10	<10	<10	<10	<10	14
		Min.	-	-	-	-	-	-	<10
		Avg.	-	-	-	-	-	-	-
Silver	50	Max.	8	0.5	0.2	<0.2	20	0.4	2
		Min.	<0.2	<0.2	<0.2	-	2	<0.2	0.5
		Avg.	-	-	-	-	-	-	-
Tin	-	Max.	<8	<8	<8	<7	<7	<4	<5
		Min.	-	-	-	-	-	-	-
		Avg.	-	-	-	-	-	-	-
Vanadium	-	Max.	<8	<8	<8	<7	10	10	<5
		Min.	-	-	-	-	<7	<7	-
		Avg.	-	-	-	-	-	-	-
Zinc	5000	Max.	<80	<100	<100	<100	<100	<100	<80
		Min.	-	-	-	-	-	-	-
		Avg.	-	-	-	-	-	-	-

NOTE: Where all values were less than the limiting sensitivity of the test, the lowest limit of detection is shown as the maximum value.

* - Median

CHAPTER IV. COLIFORM BACTERIA

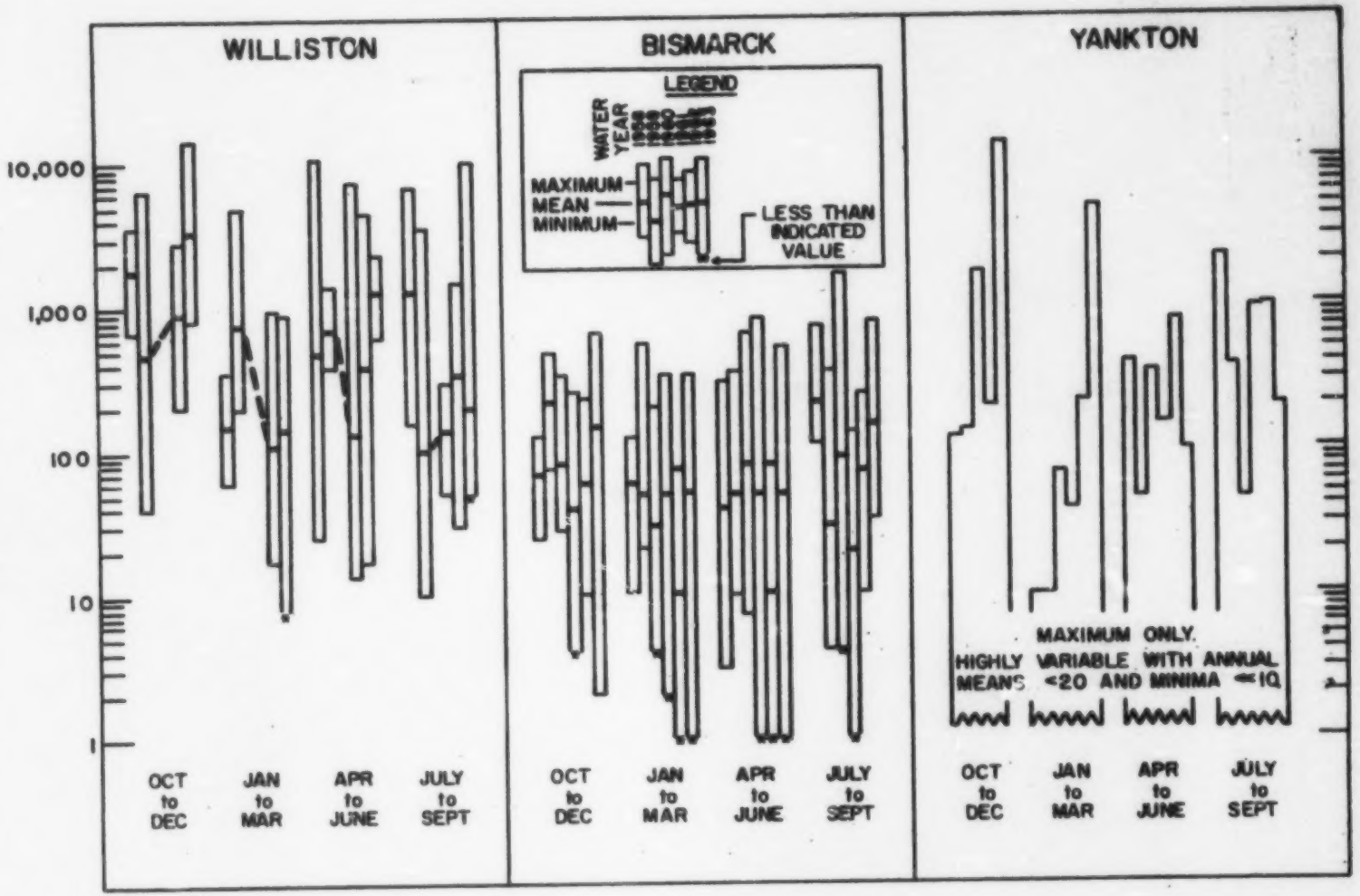
Minimum concentrations of coliform bacteria in the Missouri River are fixed by runoff from natural and agricultural lands. Locally, even lower values will follow sedimentation in reservoirs. Higher concentrations result from discharges of municipal and meat-processing wastes.

Figures 17 and 18 indicate local pollution at Williston, values common to land drainage at Bismarck, lower levels below Gavin's Point Reservoir at Yankton, and heavy bacterial pollution at Omaha, St. Joseph, Kansas City (where highest bacterial populations are found) and St. Louis. Winter concentrations averaged from 20 to 80 percent of those found during the rest of the year.

The local pollution at the Williston water treatment plant intake is noteworthy. The elevations of both the intake and the outfall from the city's sewage treatment plant seven miles downstream are at about the same elevation. Both locations are in pool from Garrison Dam. The upstream movement of some of the sewage discharge may be explained by the prevailing westerly winds blowing surface waters to the east which are subsequently replaced by a counterflow along the bottom.

Mean quarterly populations shown are generally geometric means except where the number of "less-than" values required graphic determinations based upon log-normal distributions.

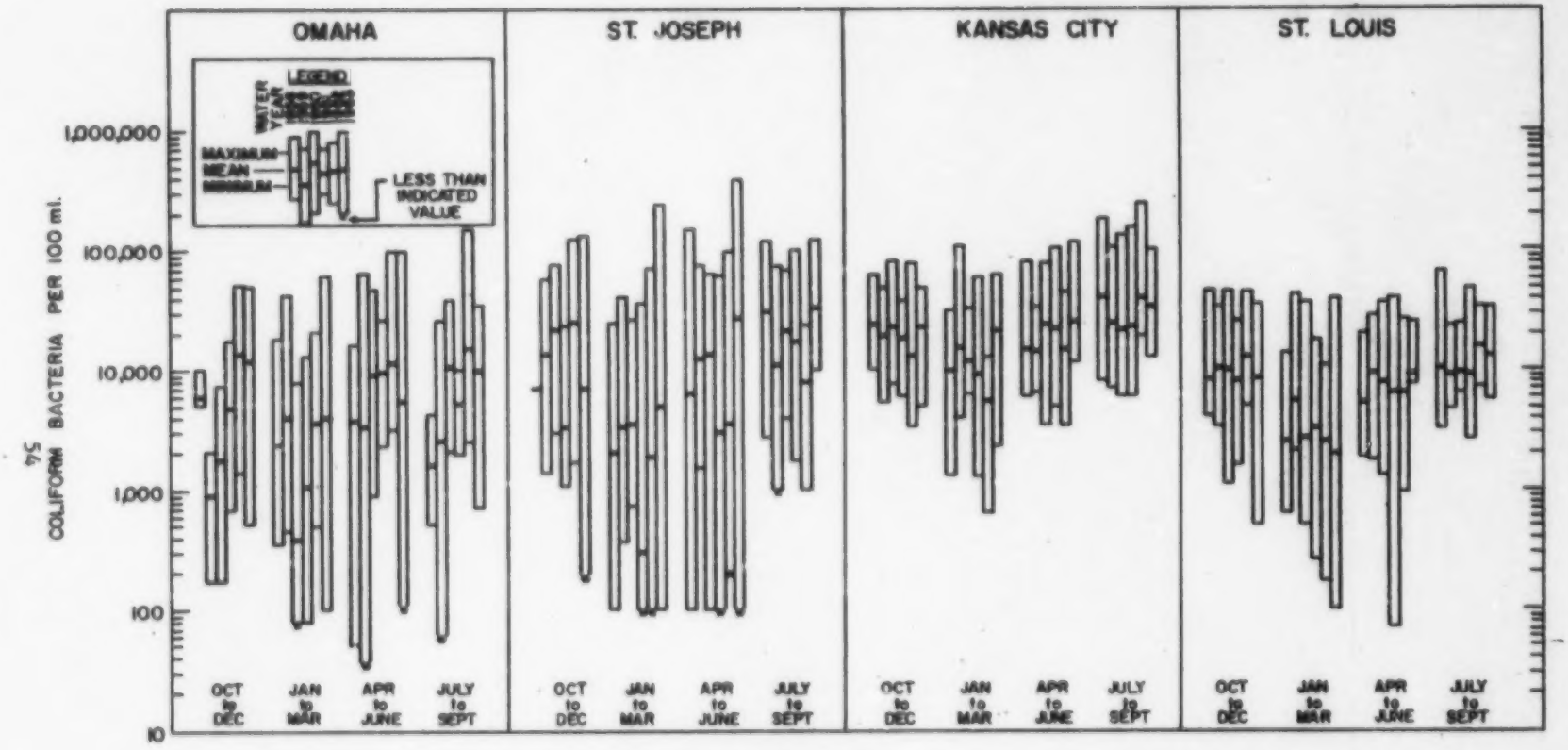
There were marked variations in mean concentrations and ranges in coliform levels with no clear-cut trends at any of the stations. Warm-weather populations at Omaha, St. Joseph, Kansas City, and St. Louis



MISSOURI RIVER STUDY

COLIFORM BACTERIA IN UPPER REACH

FIGURE 17



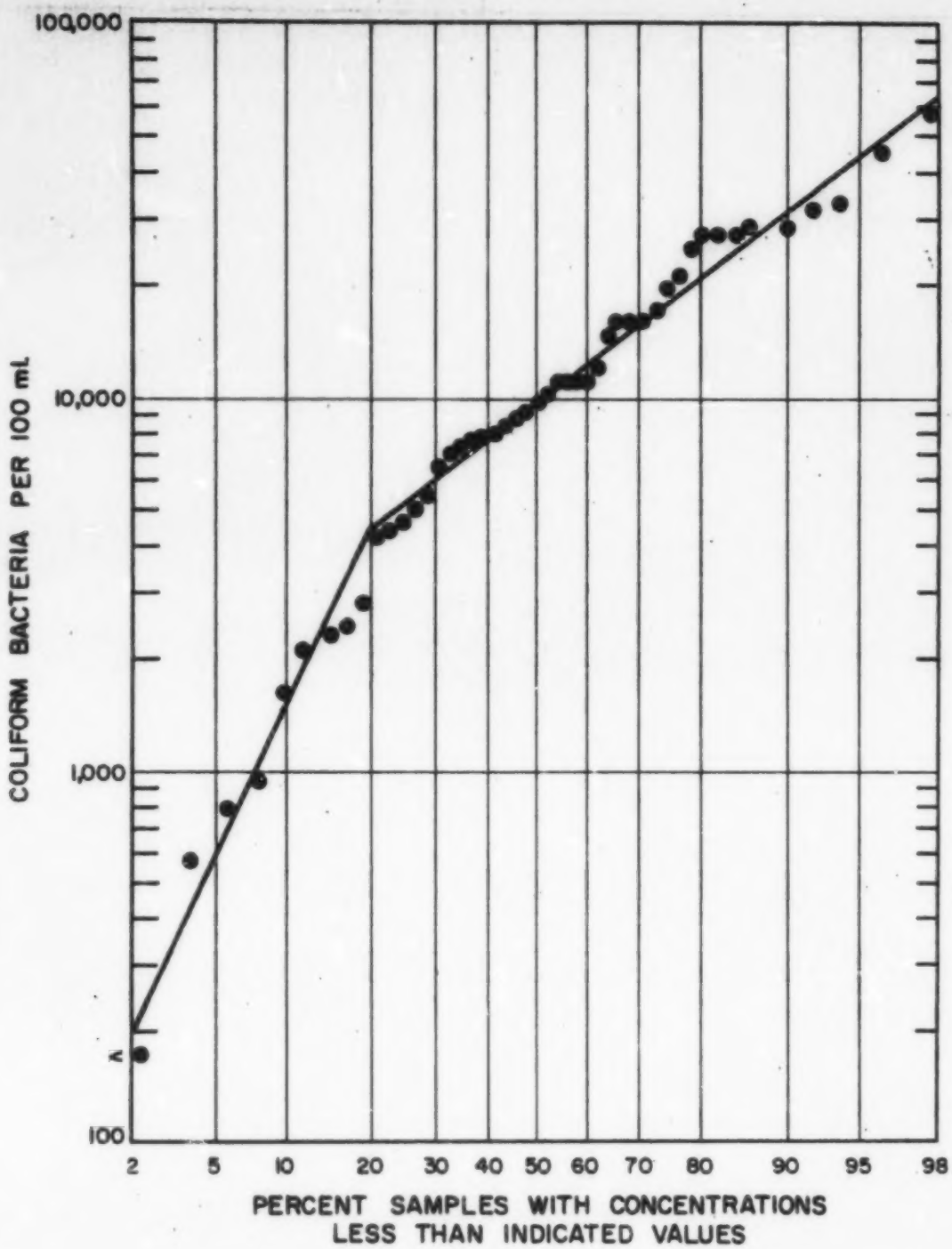
MISSOURI RIVER STUDY

COLIFORM BACTERIA IN LOWER REACH

FIGURE 18

averaged about 5,000, 10,000, 20,000 and 9,000 per 100 ml., respectively. These values exceed, by a wide margin, the bathing water standards set by 50 control agencies in North America whose limiting concentrations generally range from 1,000 to 2,400 per 100 ml.[19] The true values are undoubtedly somewhat larger since the general effect, particularly in warm weather, of the delayed incubation procedure used for the PHS Water Pollution Surveillance System is to reduce the recovery of coliform population.[20]

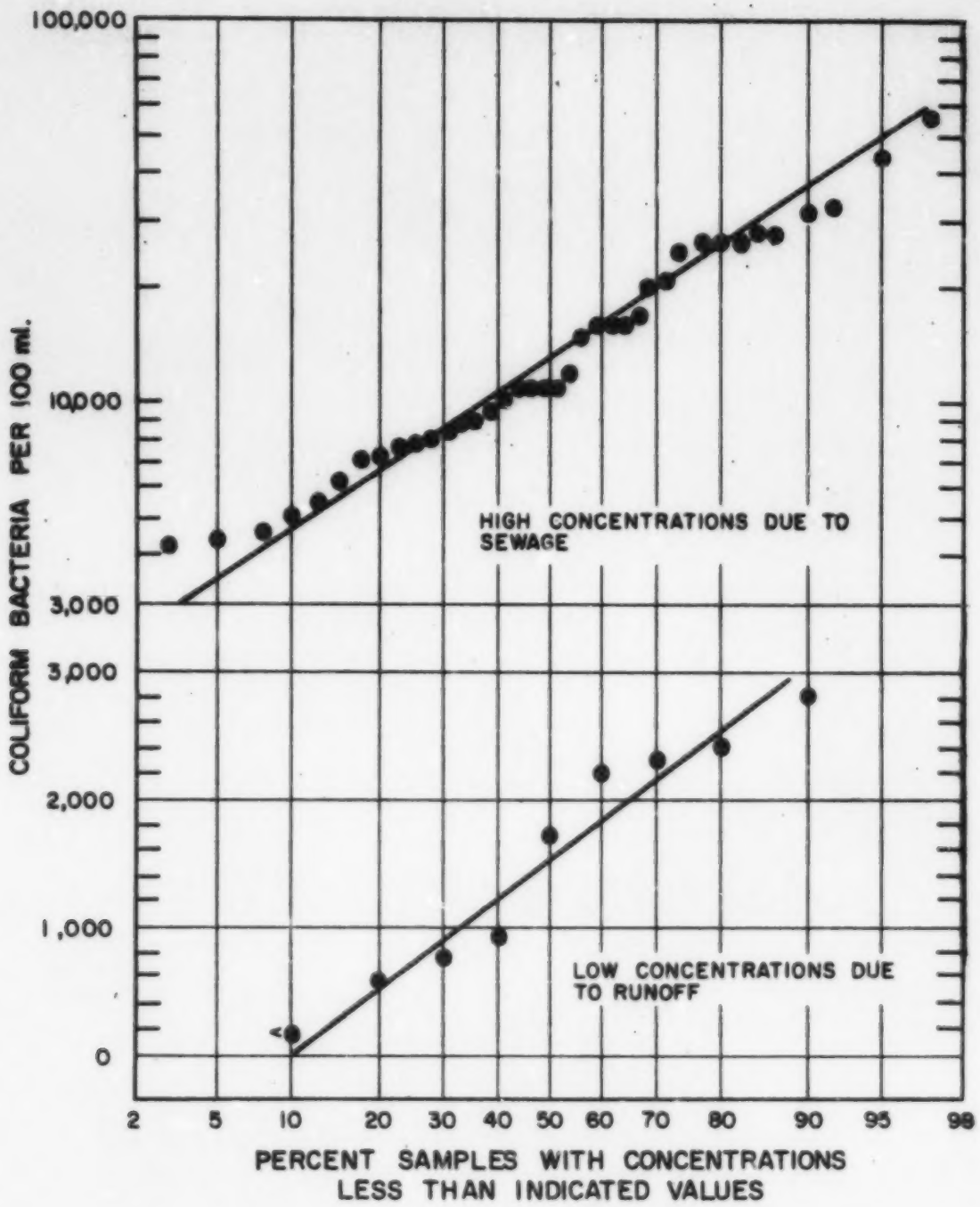
Figures 17 and 18 show relatively large differences between the mean coliform populations for successive years at any one station. These variations tended to decrease as the population levels increased, indicating that much of the variability must be due to runoff. The effect of runoff may be further demonstrated by probability analyses of the data. Figure 19 shows a fairly typical case where two different populations of high and low density are clearly indicated. Separate plots of the two populations are shown on Figure 20. The low-density population due to runoff follows the usual normal distribution while the high-density position due to municipal discharges is, as expected, log-normal.



MISSOURI RIVER STUDY

FREQUENCY DISTRIBUTION OF COLIFORM BACTERIA CONCENTRATIONS AT ST. LOUIS, WATER YEAR 1962

FIGURE 19



MISSOURI RIVER STUDY

FREQUENCY DISTRIBUTIONS OF POPULATION GROUPS OF COLIFORM BACTERIA AT ST. LOUIS, WATER YEAR 1962

FIGURE 20

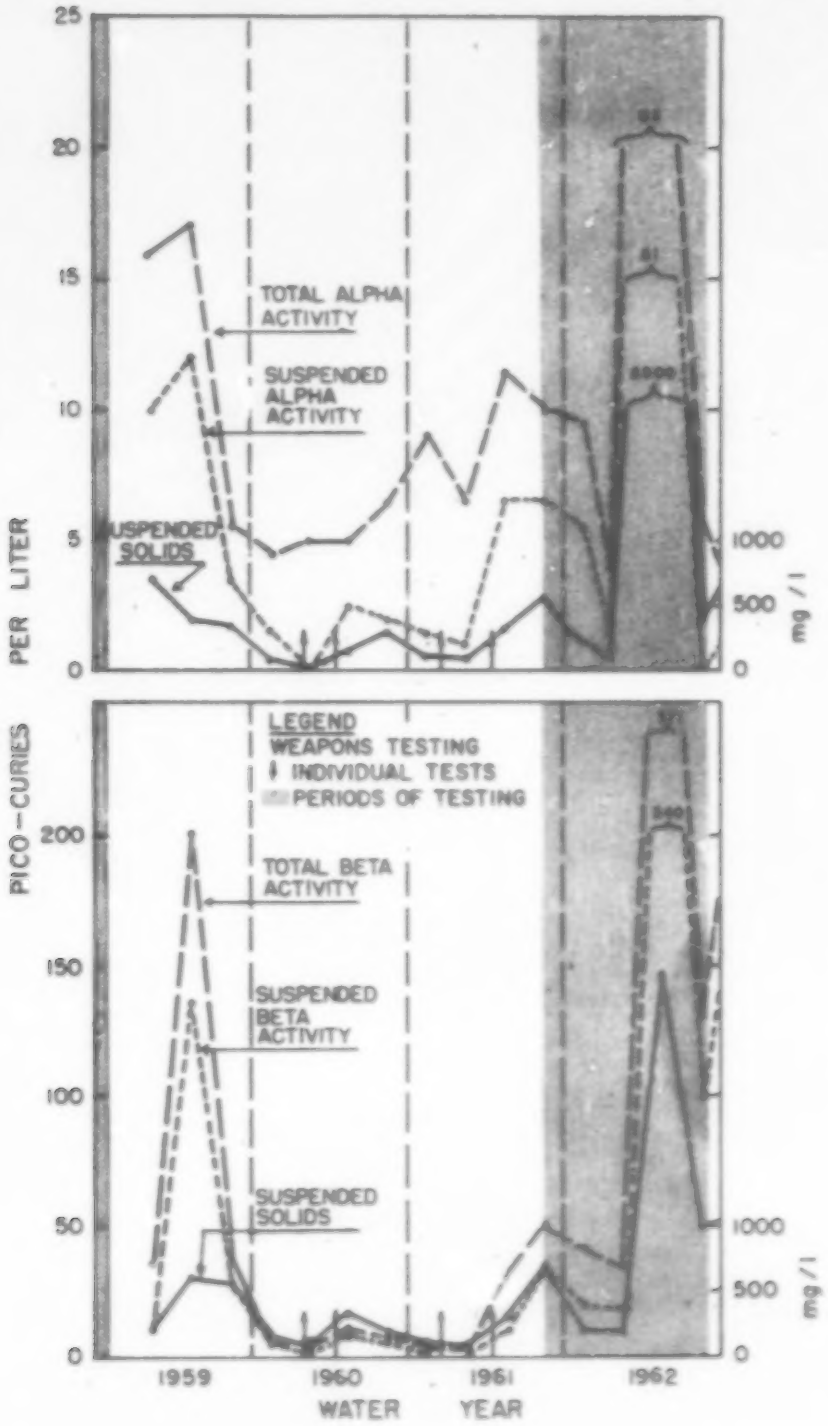
CHAPTER V. RADIOACTIVITY

Variations in levels of radioactivity in surface waters may be expected because of variations in nuclear weapons testing, in seasonal rainfall patterns, and in the concentrations of naturally radioactive suspended and dissolved materials in the water.

Figures 21 and 22 show quarterly averages of radioactivity and concentrations of suspended solids at Williston and St. Louis, respectively. Minor differences in suspended solids concentrations shown with the alpha and beta levels at any one time may occur because alpha determinations are not made on all samples. The figures show that most of both alpha and beta radioactivity is suspended.

The strong dependence of alpha activity upon suspended solids concentrations, and thus upon regional geological conditions, is clearly demonstrated. This is consistent with the nation-wide pattern.[21] It has been found that there is an average of 15 pico-curies of natural alpha activity per gram of suspended solids and that individual analyses may show a range of from 0 to 30 pico-curies per gram. The peak alpha and high beta activities at Williston in 1962 were caused by extremely high suspended solids in the sample.

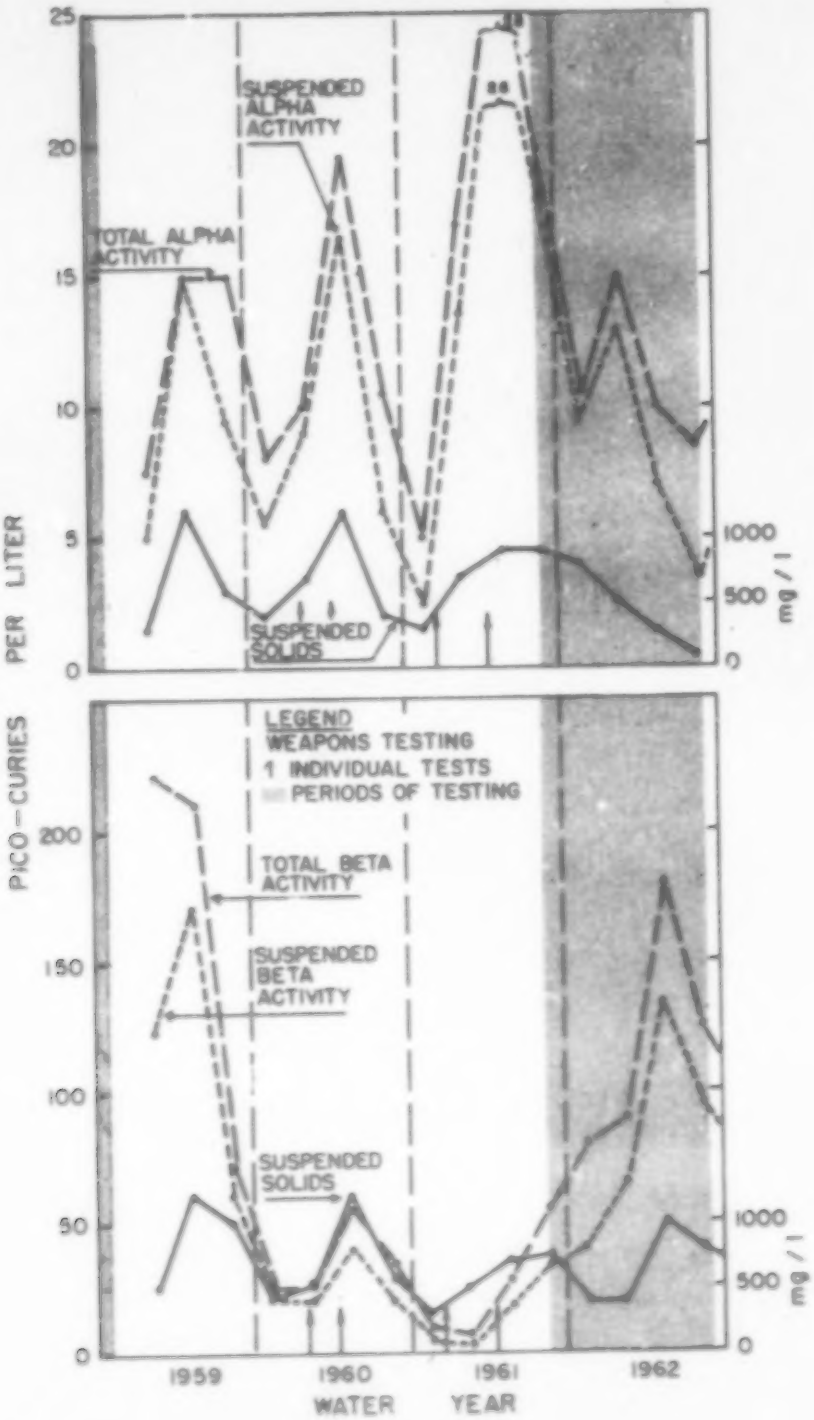
Levels of beta radioactivity, which are almost entirely due to fallout from nuclear weapons testing, were about an order of magnitude greater than alpha, and much less dependent upon suspended solids levels. The high correlation between the two derives from rainfall which collects atmospheric activity and ultimately ends up in streams where suspended solids concentrations are a function of the flow.



MISSOURI RIVER STUDY

RADIOACTIVITY AND SUSPENDED SOLIDS AT WILLISTON 1959-1962

FIGURE 21

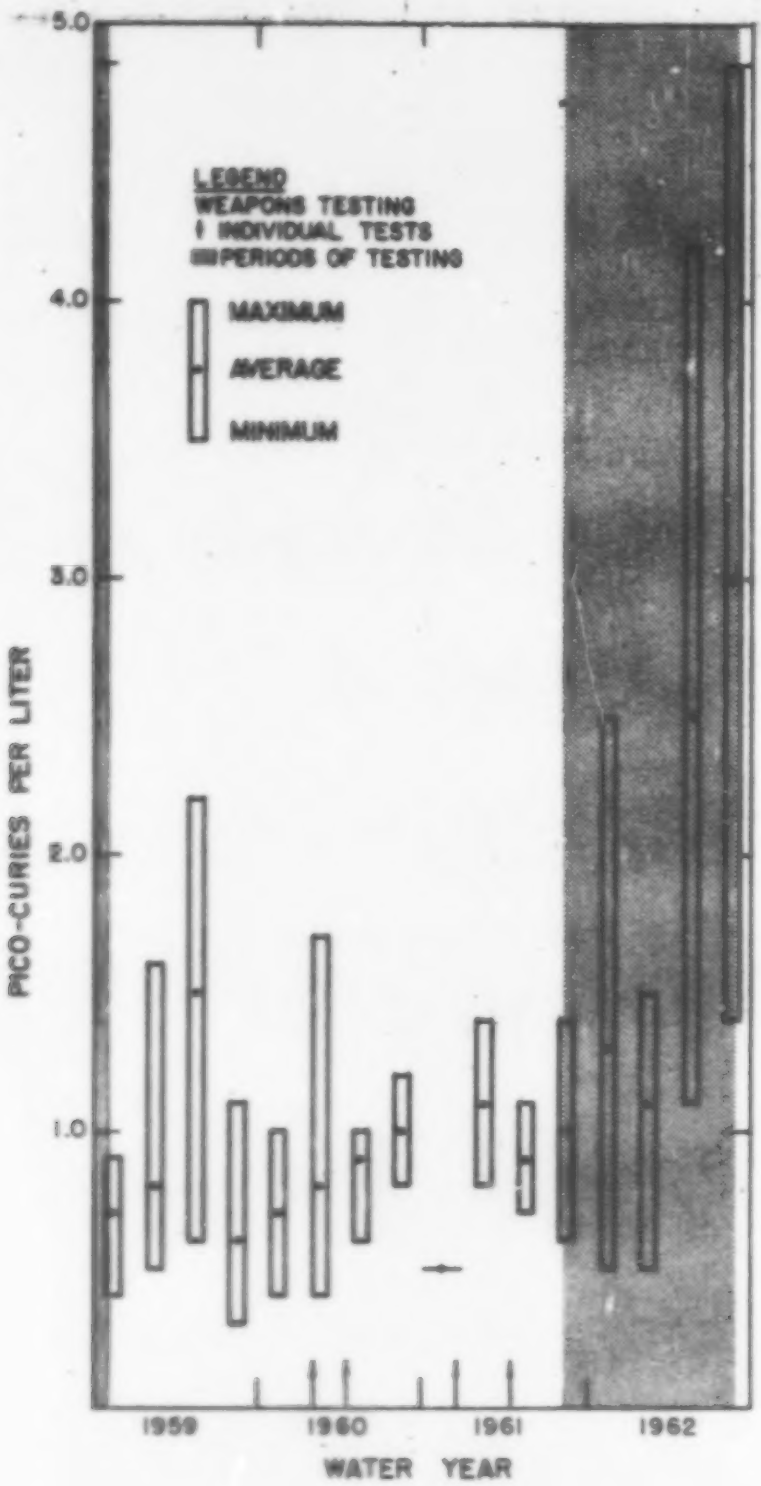


MISSOURI RIVER STUDY

RADIOACTIVITY AND SUSPENDED SOLIDS AT ST. LOUIS 1959-1962

FIGURE 22

The pattern of beta activity is repeated in the Strontium-90 concentrations shown in Figure 23. Sr-90 is due entirely to fallout, and the periods of high beta and Sr-90 radioactivity in the Missouri River are consistent with nuclear weapons tests.



MISSOURI RIVER STUDY

STRONTIUM-90 1959-1962

FIGURE 23

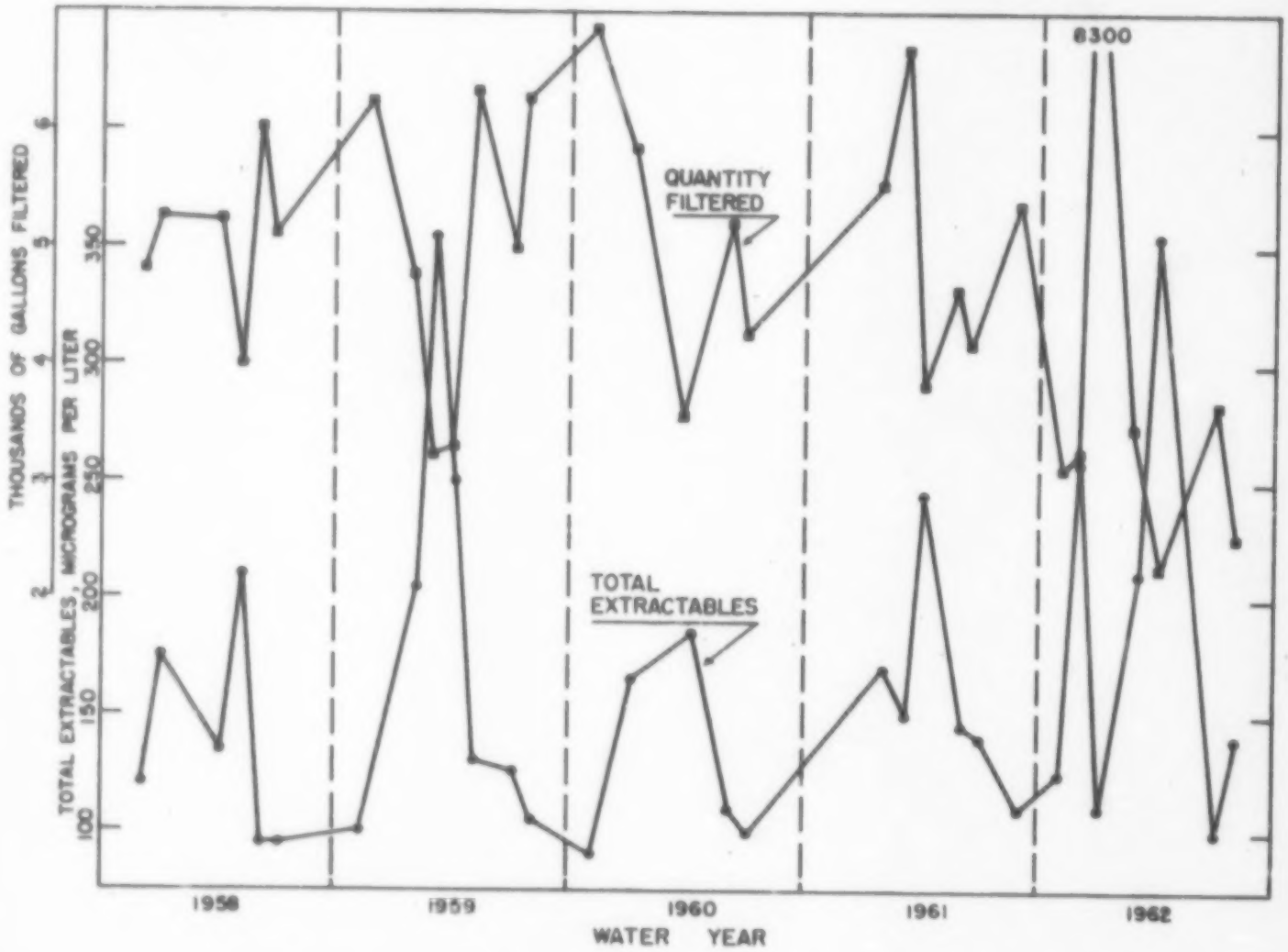
CHAPTER VI. ORGANIC ANALYSES

Organic materials have been sampled by using the carbon adsorption method. This involves passing a measured amount of water through an activated carbon column. The organic materials adsorbed onto the carbon are analysed by means of solubility separations and infrared spectrophotometry. A limited number of samples has been further examined by gas chromatography.

It has been found that the calculated concentrations of the various organic fractions are inversely proportional to the amount of water filtered. This is demonstrated by the results from the station at St. Louis shown on Figure 24. Generally, similar relationships are found for the separated fractions at St. Louis and for corresponding determinations at the other stations.

The derived concentrations of various extracts may be studied by means of flow-concentration diagrams. Figure 25, for example, shows chloroform extract concentrations at Williston and St. Louis. Best-fit curves have been fitted by eye. The apparent concentrations are about the same, so that the municipal and industrial discharges in the lower reaches of the river are not a factor here. However, there is a strong suggestion of a difference in the slope of the two curves and hence in the adsorption characteristics of the organic mixtures at the two stations.

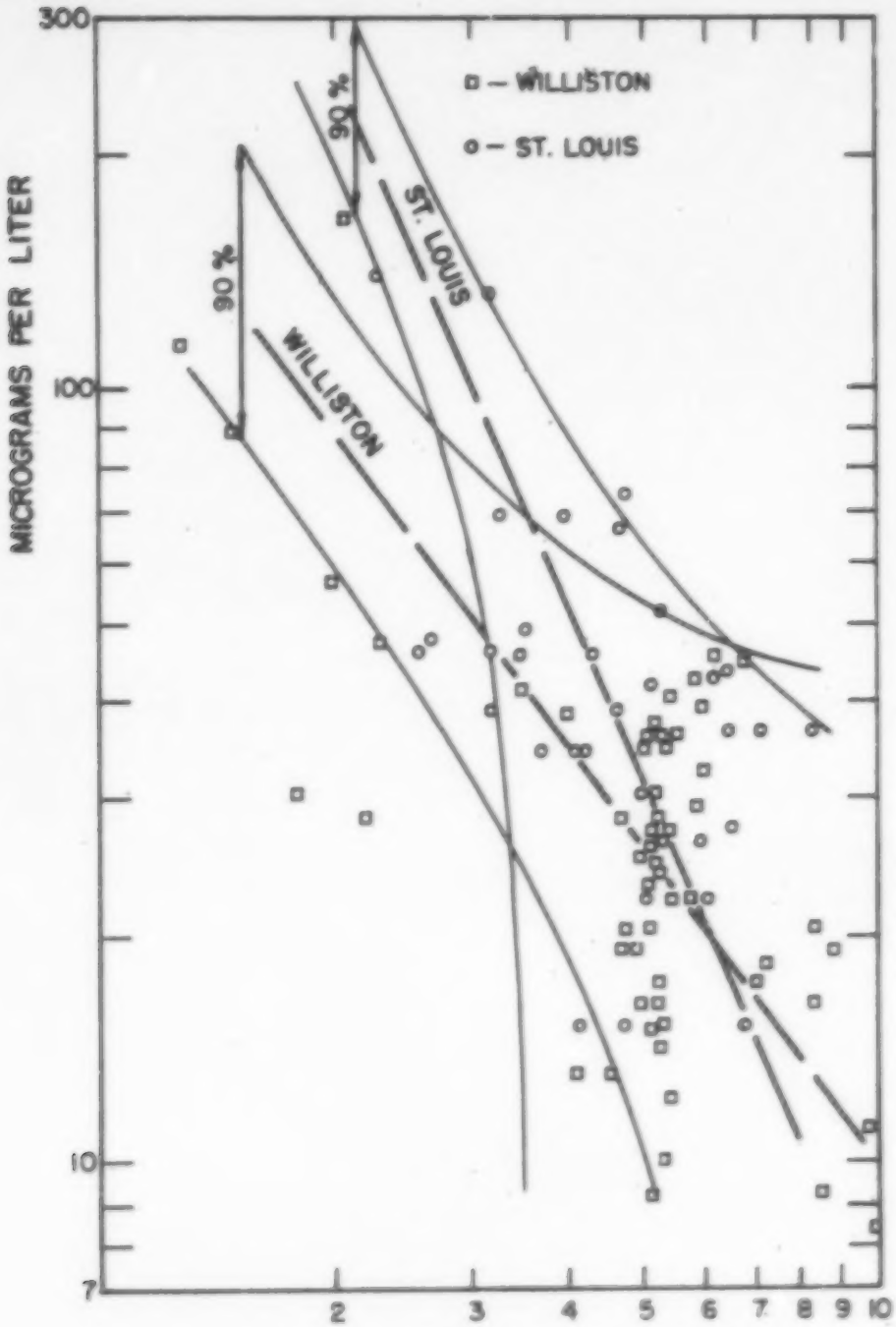
High proportions of chloroform extractables (CCE) have been suggested as being indicators of industrial pollution. Accordingly,



MISSOURI RIVER STUDY

ORGANIC ANALYSES AT ST. LOUIS

FIGURE 24



MISSOURI RIVER STUDY

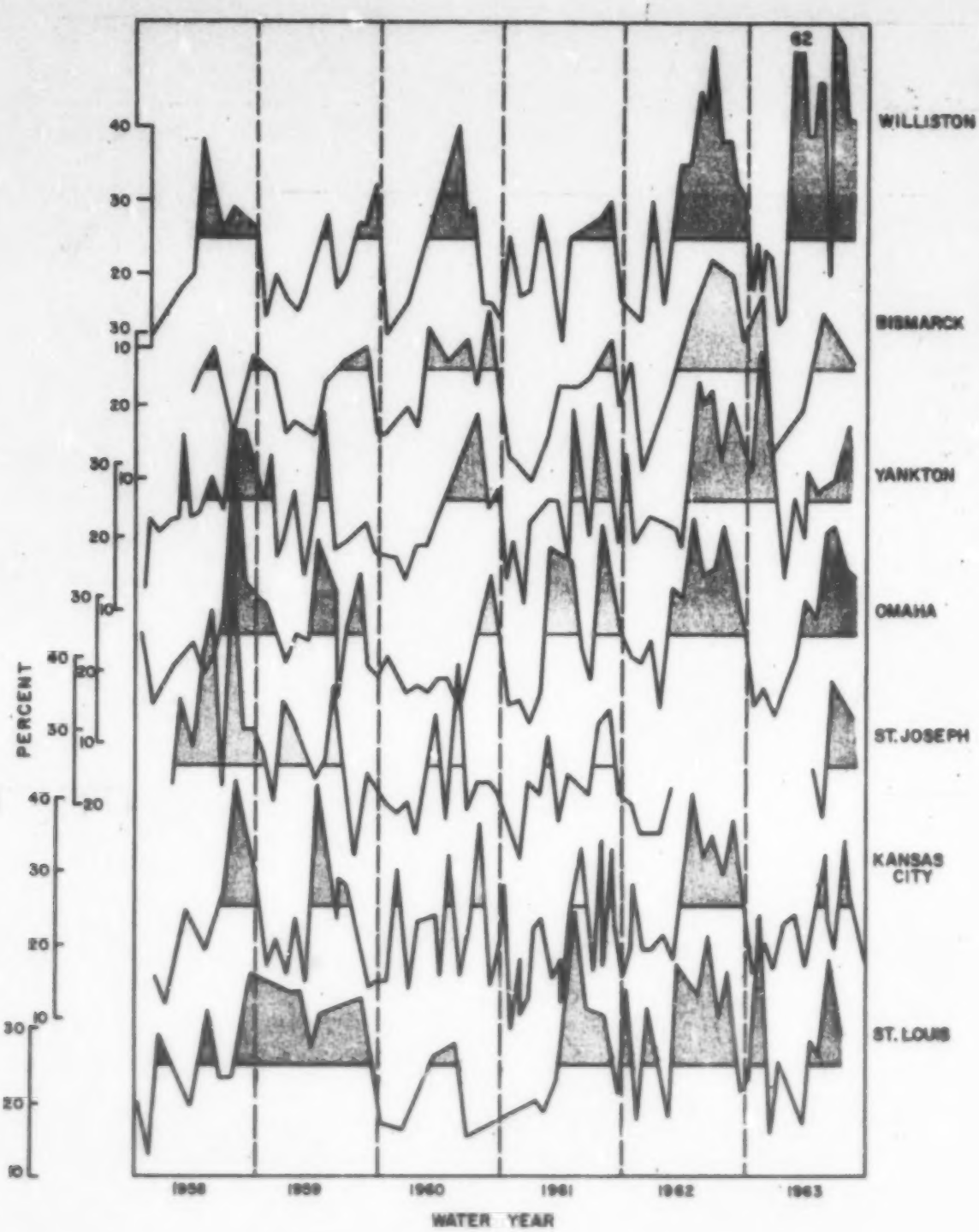
APPARENT CONCENTRATION OF CHLOROFORM EXTRACTABLES

FIGURE 25

percentages of CCE throughout the river during the five-year period, water years 1958-1962, are drawn on Figure 26. As an aid to visual comparison, values in excess of an arbitrary limit of 25% are shaded. It is seen that % CCE values are about the same throughout the river and the higher values tend to occur from April through October. This corresponds roughly with the times of higher plankton populations, BOD, and NH_3-N, although neither the cause-effect relationships nor the significance of the observations are known.

The infrared spectra of the CCE-aromatic fractions at Bismarck and St. Louis were compared for water years 1958-1962. Table 15 shows that absorption peaks at certain wave lengths were characteristically present at either or both stations. The following differences were thus indicated at St. Louis when it is compared with Bismarck:

1. The number and variety of substances bearing oxygen are increased, as suggested by the frequency of occurrence of absorption bands characteristic of ketones, ethers, acids, aromatic esters and aromatic aldehydes. On the other hand, the spectra indicate that the number and complexity of organic substances present in the water is greater.
2. The degree of substitution on aromatic nuclei is greater; for example, nitrated aromatic materials are present more frequently. Such substituted aromatic compounds have been classically associated with chemical industrial pollution.



MISSOURI RIVER STUDY
PERCENT CHLOROFORM EXTRACTABLES
1958-1963

FIGURE 26

Table 15

OCCURRENCES OF SPECIFIC INFRA-RED ABSORPTION BANDS IN AROMATIC FRACTIONS

Wavelength	Configuration	Estimated Percent Occurrence Bismarck	St. Louis
6.15	Alkene C=C	90	79
6.3	Aromatic ring	93	100
6.5	Aromatic ring, $-NO_2$	0	25(mostly winter)
7.7-7.8	Alkane, Alkene, -OH, -COOH	31	5
7.9-8.0	Ester, aldehyde, ketone, acid	60	98
8.1	Ester, aldehyde, ketone, ether	2	16(mostly winter)
8.4-8.5	Ester, aldehyde, ketone, ether di- and tri-substituted aromatic	95	100
8.8	Mono-di-tri-substituted aromatic aldehyde, ketone, -OH	27(none in 1962)	0
9.1	Ether, -OH, Mono-, di-, and tri-substituted aromatic	41 " " "	100
9.3-9.4	Aldehyde, -OH, Mono-, di-, and tri-substituted aromatic	22(begin 7/60)	7(begin 7/61)
9.8	Aldehyde, -OH, di- and tri-substituted aromatic	70	100
10.3	Aldehyde, di- and tri-substituted aromatic	37	91(generally weak)
11.2	Alkane, alkene, aldehyde, acid	67	7
11.6	Aldehyde, alkane, alkene, substituted aromatic	12	95
12.3	Alkane, alkene, di- and tri-substituted aromatic	96	100
12.8	Alkene, di- and tri-substituted aromatic	5	19
13.3	Alkene, mono-di- and tri-substituted aromatic	87	100
13.8	Mono-, di-, and tri-substituted aromatic	91	90
14.3	Mono-di-, and tri-substituted aromatic	88	93

Specific identifications of such refractory compounds as pesticides are being made with new analytical techniques. Examinations of the aromatic fractions of six carbon-chloroform extracts from St. Louis have recently been made using infrared characterization and thin-layer chromatography as well as micro-coulometric titration and electron-capture gas chromatographic analyses. The collective results of these procedures verified the presence of dieldrin during October 13-27, 1958; August 15-30, September 15-30, October 15-31, November 15-20, and December 16-31, 1963 in apparent concentrations of from 0.002 to 0.004 ug/1. DDT, DDD, DDE, and endrin were absent from these samples. As shown on Figure 25, these concentrations are minimal. Concentration values are calculated from the quantitative gas chromatographic analysis of the aromatic fractions of CCE, and may be assigned the units of micrograms per liter. In light of the unknown efficiency of carbon adsorption sampling for these compounds, the reported values represent minima, the actual values being equal to or greater than the reported values.

These particular samples were arbitrarily selected for study and are presumed to represent late summer and fall conditions near the mouth of the Missouri River. Finding pesticide in the October 1958 sample is particularly significant. This demonstrates that, as new analytical techniques are being developed and become routine surveillance tools, the stored extracts provide a source of historical data that are otherwise not available.

* *

NOTE ADDED IN PROOF. Chromatographic analysis of grab samples of Missouri River water showed the following concentrations of dieldrin: Williston, 1/20/64 - 0.016 ug/1, 2/3/64 - 0.025 ug/1; Bismarck, 1/20/64 - 0.040 ug/1, 2/3/64 - 0.025 ug/1; St. Joseph, 1/20/64 - 0.023 ug/1, 2/3/64 - 0.020 ug/1, 2/17/64 - 0.020 ug/1; Kansas City, 1/20/64 - 0.040 ug/1, 2/3/64 - 0.031 ug/1, 2/17/64 - 0.029 ug/1. These data suggest that concentrations based on carbon filter samples are low by perhaps an order of magnitude. Again, DDT, DDD, DDE, and endrin were absent.

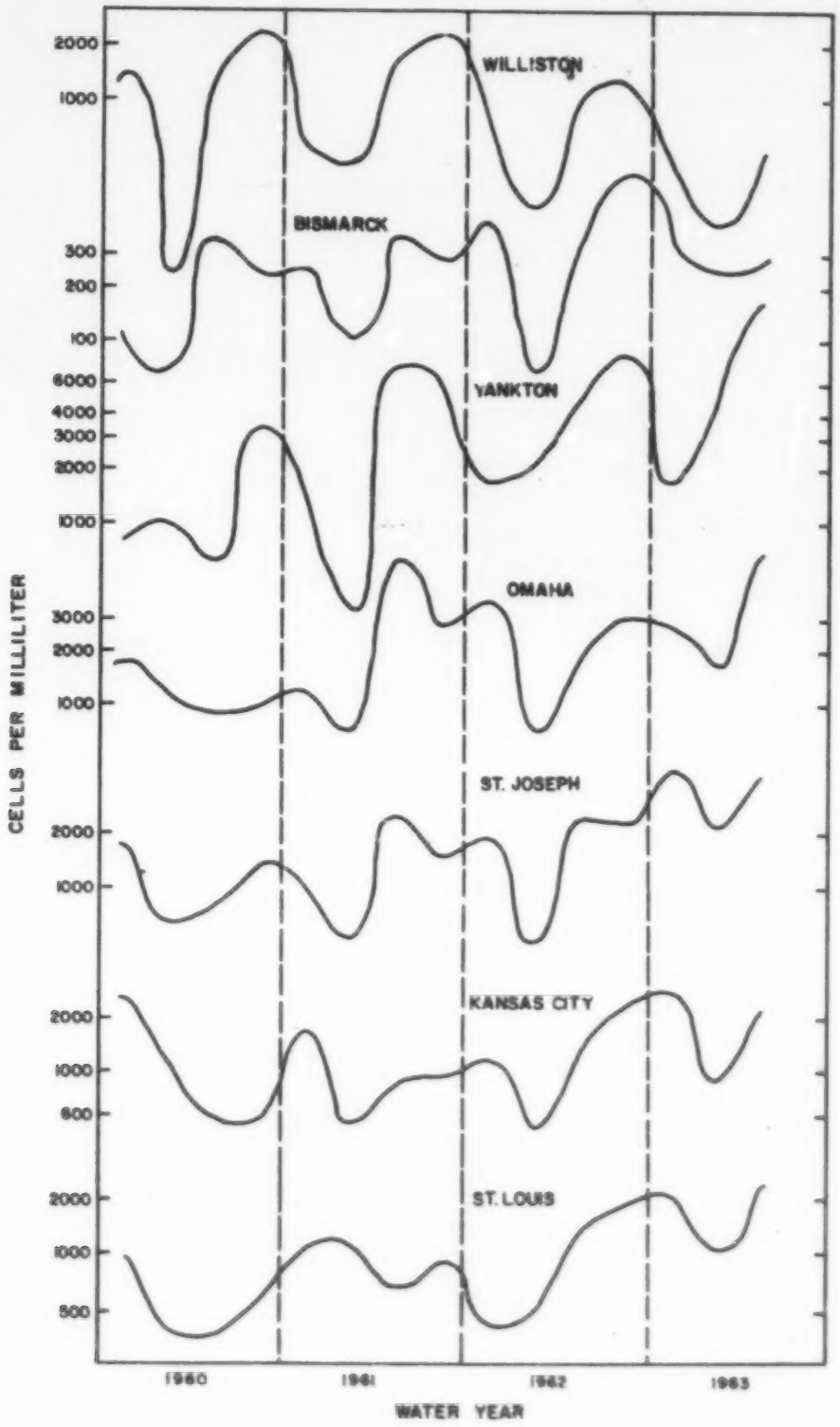
CHAPTER VII. PHYTOPLANKTON

Quarterly averages of total plankton in the Missouri River are shown on Figure 27. Essentially all of the cells enumerated therein were phytoplankton. During the period of study, populations averaged about 650 per ml. at Williston, 250 at Bismarck, 2,500 at Yankton, and then dropped more or less uniformly to 900 at St. Louis.

The reason for the minimum at Bismarck is not discernible from available data; the chemical quality was not markedly different from that at Williston and Yankton, although the random pattern of chemical quality variations were unique to that station. Similarly, present data do not show the reason for the maximum populations at Yankton. It is presumed that limnological conditions within Gavin's Point Reservoir, which is located only six miles above the sampling point, constitute a major factor. Fort Randall and Oahe Reservoirs may also be important. Below Yankton, turbidity increased so that the amount of light available for plankton growth was reduced and populations decreased. However, other factors may also be operating and perhaps controlling the population levels.

Figure 27 also shows that plankton populations were increasing in numbers at all stations except Williston. Examination of other data for Williston shows no apparent reason for this difference.

The great bulk of the plankton consists of diatoms and variations noted above were mostly due to changes in diatom populations. The more precise identification of diatoms has been possible because



MISSOURI RIVER STUDY
TOTAL PLANKTON, 1960 - 1963
FIGURE 27

of their distinct taxonomic characteristics. Algal species diversity is generally considered an index of the health of a stream. The Missouri River contains a diversified diatom population which, during water years 1961-1963, varied as shown in Table 16. A more exhaustive analysis of species diversity which permits comparisons with other PHS Water Pollution Surveillance System stations has been previously published.[22]

The variations in diatom and other groups are summarized in Table 17. There were general increases in populations of all types of phytoplankton at most stations.

Minimum plankton populations were found during the winter. Diatoms tended to have maxima in the late spring and again in the fall. These blooms were mostly caused by Stephanodiscus astraea. Green and blue-green algae populations generally followed a simpler pattern with a maximum in the summer.

On occasion, high populations of taste and odor-producing organisms were found The diatom Asterionella formosa was found throughout the river, and on one occasion (June 1961 at St. Joseph) bloomed along with another troublesome species, Synedra ulna for a total population of about 13,000 per milliliter.

Certain notable patterns can be seen in the numbers of diatom species observed in the plankton samples (Table 18). The middle reach from Yankton to Omaha had the least number of species. There was an abrupt drop in numbers of species at all stations in 1963. An analysis of variance showed that these differences were significant at the 99% level. Variations in species numbers between quarters were not shown

Table 16

OCCURRENCE OF MOST ABUNDANT DIATOM SPECIES

	Williston	Bismarck	Yankton	Omaha	St. Joseph	Kansas City	St. Louis
Achnanthes lanceolata					2		
Asterionella formosa	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	2 3	1 3
Cocconeis pediculus		1	2				
Cyclotella meneghiniana	2		2	1 2 3	1 2	1 2 3	1 3
Cyclotella pseudostelligera	3		2				
Diatoma elongatum			1 2				
Diatoma vulgare	1 2 3	1 2 3	1 2 3	3	1		
Fragilaria capucina	1		1 2	1	3	3	
F. construens					1 2 3	1 2 3	1 2 3
F. crotonensis	1 3		1 2	1	1 2	1	1
Melosira ambigua			1 2	2		1	
Melosira granulata			1 2	1 2 3	1 2 3	1 2	1 2 3
Cymbella sp.				3			
Navicula sp.	2 3	1 2		3	1 2		
Nitzschia sp.		2 3	1 2	1 2	1 2 3	1 2 3	1 2 3
Stephanodiscus	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
S. hantzschii	1 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
S. niagarae	1 3	1	1 2	1 2			2
Stephanodiscus sp.		1 3	1 2	1		1	
Surirella ovata				2		1 2	
Synedra ulna	1 2 3	1 2		2 3	1 2	1 2	1 2
Cyclotella sp.					3		

Note: 1-Water Year 1961 2-Water Year 1962 3-Water Year 1963

Table 17

APPARENT TRENDS IN PLANKTON POPULATIONS, 1960-1969

	Diatoms	Green Algae	Blue-green Algae	Flagellates
Williston	decrease	increase	*	*
Bismarck	increase	increase	*	*
Yankton	increase	*	increase	increase
Omaha	increase	increase	increase	increase
St. Joseph	increase	increase	increase	increase
Kansas City	increase	increase	increase	increase
St. Louis	increase	increase	increase	increase

*None Detected

Table 18

AVERAGE NUMBER OF DIATOM SPECIES - 1961-1963

Water Year	Quarter	Williston	Bismarck	Yankton	Omaha	St. Joseph	Kansas City	St. Louis	Year Mean
1961	1	31	41	29	31	47	38	42	
	2	38	46	17	32	44	35	44	
	3	44	37	22	23	39	42	51	
	4	37	42	30	18	43	44	45	
	Mean	38	42	25	26	43	40	46	37
1962	1	31	15	34	38	43	53	51	
	2	25	18	30	7	43	45	55	
	3	42	28	26	27	34	35	30	
	4	43	34	28	26	34	34	28	
	Mean	35	24	30	25	38	42	44	34
1963	1	22	23	18	20	31	30	31	
	2	25	20	10	10	35	25	22	
	3	23	29	9	14	19	21	27	
	4	31	35	16	18	34	29	17	
	Mean	25	27	13	16	30	26	24	23
	Station Mean	32	31	22	22	37	36	38	

to be significant. Species numbers are considered to be inversely related to enrichment, and their general decline is an indication of environmental enrichment.

All of the more abundant genera of green algae found in the Missouri River are pollution tolerant forms commonly found as dominants in waste stabilization ponds and other enriched waters. These groups, along with other selected organisms which are considered trophic indicators are listed in Table 19. The general trend is for increases of most types of organisms, particularly those that are indicators of polluted or eutrophic waters. In the case of the Missouri River data, the mesotrophic and eutrophic indicators have been considered more useful than the oligotrophic forms in interpreting water quality trends.

Summarizing, the plankton data indicate a diversified population which increased in total numbers, particularly pollution-tolerant species and genera. The net impression from these data is that of worsening water quality conditions.

Table 19

CHANGES IN POPULATIONS OF INDICATOR SPECIES AND GENERA

	Williston	Bismarck	Yankton	Omaha	St. Joseph	Kansas City	St. Louis
SPECIES							
Oligotrophic (clean water)							
Stephanodiscus niagarae		-	-	-			-
Mesotrophic							
Fragilaria crotonensis			+	+	+	+	+
Fragilaria capucina	-		-	-	+	+	
Eutrophic (polluted water)							
Surirella ovata				-		-	
GENERA							
Oligotrophic (clean water)							
Dinobryon			-				
Chrysococcus	+	+	+	+	+	+	+
Mesotrophic							
Crucigenia	+						
Actinastrum		+		+	+	+	0
Eutrophic (polluted water)							
Ankistrodesmus		+		0	0	0	0
Raphidiopsis	+		+	+		+	+
Scenedesmus	0		-	+	+	+	+
Chlamydomonas	+			0	+	+	0
Oscillatoria	-			-			
Euglena	+	+	+	+	0	+	+

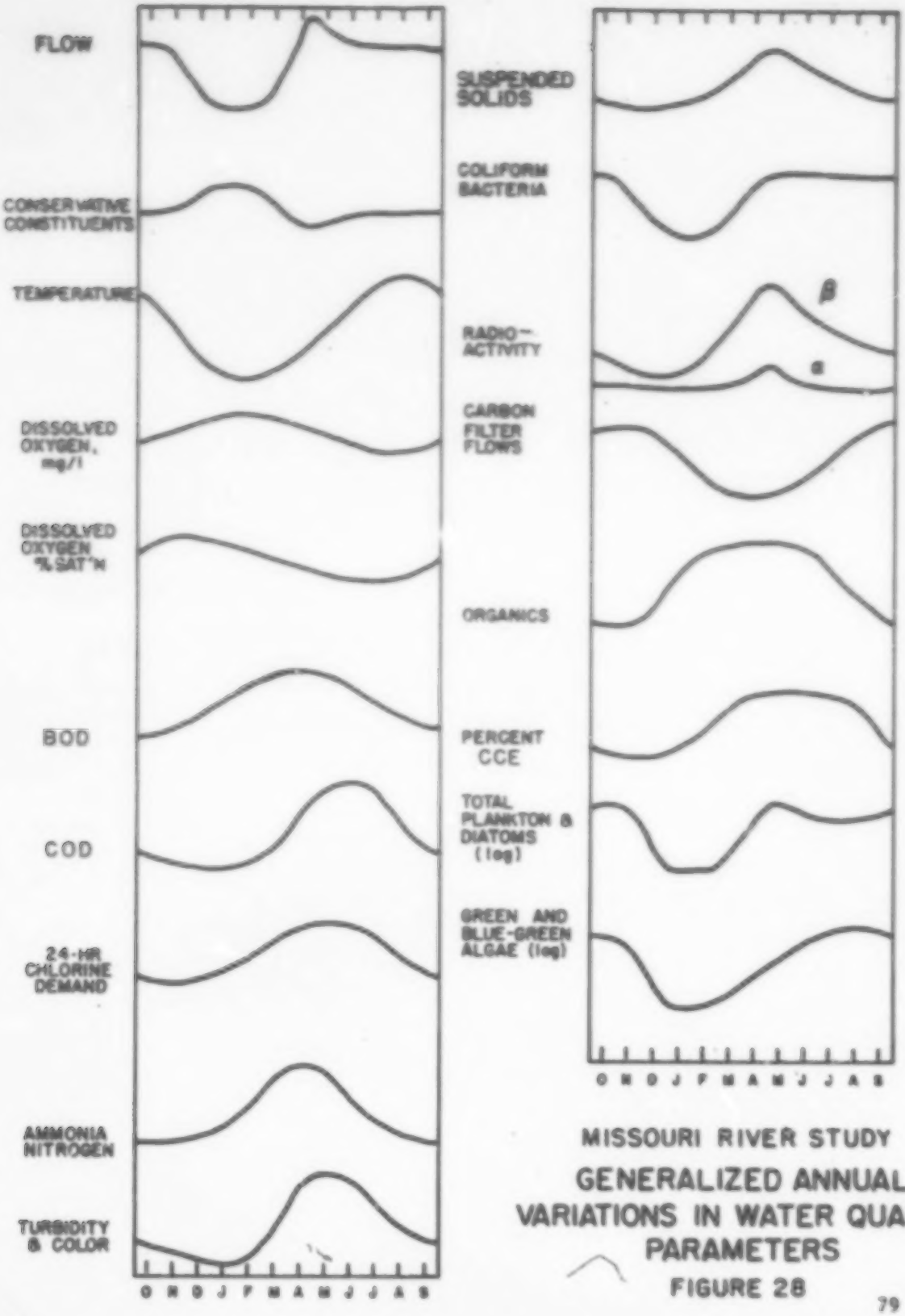
NOTE: + = Increase
- = Decrease
0 = No Change
Blank = Not Reported

CHAPTER VIII. DISCUSSION AND CONCLUSIONS

The chemical and biological characteristics of the Missouri River show, in varying degrees, the effects of tributaries, impoundments, and waste discharges. Figure 28 summarizes annual variations of selected water quality parameters in the river. The balance of the constituents varied in a random manner. Among those parameters which varied systematically, some cause and effect relationships are both known and demonstrated on Figure 28. These include the inverse relationships of flow vs. concentration of conservative constituents, and temperature vs. dissolved oxygen levels. Direct relationships include temperature vs. plankton populations and coliform bacteria levels; flow vs. suspended solids, turbidity, and color; and algae populations vs. maximum dissolved oxygen saturations.

Figure 28 also indicates that the flows through carbon adsorption columns were affected by a combination of suspended solids, turbidity, and plankton. Certainly the apparent concentrations of the various organic extracts were inversely proportional to these flows.

There are a number of other interrelationships which are suggested on Figure 28, but which are at present uncertain. Seasonal variations in BOD, COD, 24-hour chlorine demand and ammonia nitrogen were generally similar but enough out of phase to preclude direct comparisons. There is an apparent dependence of COD upon the suspended load of the river which requires further study. The percent CCE and plankton populations followed reasonably similar patters; this may provide a key to the natures



MISSOURI RIVER STUDY

GENERALIZED ANNUAL VARIATIONS IN WATER QUALITY PARAMETERS

FIGURE 28

of both the COE and the organic composition of mixed plankton populations. In any event, similar examinations of PHS Water Pollution Surveillance System data from throughout the country will refine these tentative conclusions.

On the Missouri River, the pattern of most parameters at most stations is fairly uniform. The trends that are apparent from the present data are listed on Table 20.

In addition to the interrelationships and trends listed above, this study disclosed the following:

> In general, concentrations of conservative constituents were reasonably consistent and well within limiting values for all beneficial uses. By U.S. Geological Survey standards,[18] the waters are hard, and municipal softening is generally practiced throughout the basin. On four occasions, twice for sulfate and once each for iron and manganese, the river waters slightly exceeded the Public Health Service Drinking Water Standards. However, these values were associated with the below normal flows that prevailed during the study period, and would be even less likely during normal years. Under future conditions of development with increased consumptive use, conservative constituents may become a matter of concern. At that time, routine sampling of most of the tributaries will be required in order to establish material balances and an adequate understanding of the causes of changes in water quality.

Table 20

OBSERVED TRENDS IN WATER QUALITY PARAMETERS

	Williston	Bismarck	Yankton	Omaha	St. Joseph	Kansas City	St. Louis
Dissolved Oxygen	*	*	-	+	-	*	*
COD	*	*	+	+	*	*	+
Chloride	*	*	+	*	*	*	+
Alkalinity	*	+	+	+	+	+	+
Hardness	*	+	+	+	*	+	+
TDS	*	+	*	-	*	*	*
NH_3-N	*	*	*	+	*	*	*
Total Plankton	*	+	+	+	+	+	+
Diatoms	-	+	+	+	+	+	+
Green Algae	+	+	*	+	+	+	+
Blue-greens	*	*	+	+	+	+	+
Flagellates	*	*	+	+	+	+	+
Indicators							
Oligotrophic	+	*	*	*	+	+	+
Mesotrophic	*	+	*	+	+	+	+
Eutrophic	*	+	+	+	+	+	+

*None Detected

Trace elements, particularly copper, varied widely in the semiannual composites. Adequate information requires more frequent discrete sampling at fewer stations.

Dissolved oxygen levels are dependent upon the season and the time of day. Minimum values of 4 mg/l or less were found at Omaha, Kansas City, and St. Louis; these are consistent with the BOD levels resulting from waste discharges. Since these oxygen levels were found during daylight hours, true minima are lower. In addition, these samples were taken from water plant intakes located upstream from the cities, and even lower values may be expected below locations of waste discharges from those cities. It was found that trends in dissolved oxygen are best detected and studies in terms of saturation values.

Bacteriologically, the Missouri River showed the effects of waste discharges at all stations except Bismarck and Yankton. Warm weather populations of coliforms at Omaha, St. Joseph, Kansas City, and St. Louis averaged about 5,000, 10,000, 20,000 and 9,000 per 100 ml., respectively, far in excess of coliform standards for recreational waters.

Radioactivity was mostly suspended. Consequently, the natural alpha activity was closely related to suspended solids concentrations. Beta activity also followed suspended solids, but was more strongly affected by nuclear bomb testing. Strontium-90 also reflected bomb tests.

The results of organic analyses showed presence of dieldrin in the water at St. Louis. The entire significance of these observations is at present unknown. The adsorption characteristics of the chloroform extractables together with their qualitative

interrelationships with plankton populations suggest that much additional knowledge of the organic constituents in streams can be derived from the carbon adsorption method.

The plankton studies showed diversified and variable populations with fairly frequent occurrences, and on one occasion, a bloom of taste and odor-producing algae. There were marked increases in numbers of green algae throughout the river and in numbers of diatoms and/or other forms at Yankton and Omaha. These and concurrent increases in pollution-tolerant species and genera suggest worsening water quality conditions in the Missouri River. Oahe Reservoir was being filled during the study period, and it is possible that this change was being reflected. In any event, a limnological investigation conducted after the filling of the mainstem reservoirs is necessary for a more complete understanding of the chemical and biological quality at and above Yankton.

Below Yankton, plankton populations and compositions are reasonably consistent from Omaha to St. Louis. Fish populations have not been evaluated. No fish kills were reported for the river during calendar years 1960 through 1962,[22, 23, 24] although some were noted in tributaries, so that there is no evidence of batch discharges of toxic wastes or of severe short-term oxygen depletion.

Summarizing, the present waters of the Missouri River are, with treatment, suitable for municipal and industrial uses. Recreational values are severely limited in the lower reach because of bacterial pollution from

municipal and industrial waste discharges. Those trends that were found were generally toward poorer water quality; scheduled construction of waste treatment facilities should provide for reversal of some of these trends.

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